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AEROSOL CHARACTERISTICS IN THE MARINE BOUNDARY LAYER OVER THE STRAITS OF GIBRALTAR - JUNE 1986

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Measurements of aerosol characteristics in the marine boundary layer were taken during a two-week cruise through the Straits of Gibralter. Observations of Aitken nuclei concentration, aerosol size spectra (0.01-100 μm diameter), aerosol composition, visibility (scattering coefficient), optical depth (sun photometry), temperature, humidity, winds and cloud cover were acquired during daylight hours. The data show that surface visibility fluctuations correlate well with particle concentration in the 0.56-1.78 μm size range. Surface relative humidity and particle composition appear to be the factors that control concentration in this size range.

These data will be used as ground truth for techniques which retrieve aerosol data from satellites. This experiment was well suited for such an application, since there was little cloud cover to obscure satellite measurements; and comprehensive, consistent aerosol measurements were successfully taken.

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1.0 INTRODUCTION

Under sponsorship of the Naval Environmental Prediction Research Facility (NEPRF) through Contract No. N00014-85-C-2393 with the Naval Research Laboratory (NRL), Calspan Corporation obtained sun photometry, meteorological and aerosol physics data during the Naval Ocean Research & Development Activity (NORDA) cruise 707-86 aboard the USNS LYNCH (T-AGOR 7) -- i.e., the Gibraltar Experiment portion of the Western Mediterranean Circulation Experiment.

Data were acquired from 17 to 30 June 1986 during daylight hours in the Straits of Gibraltar. A data volume summarizing the data set was issued in January 1987. This final report provides analyses and interpretation of the data.

Radiosonde, sun photometry, visibility and other meteorological data, and Casella impactor samples were obtained by NEPRF personnel while aboard the USS America (19-26 June) during a cruise from Palma, Spain to the Straits of Messina (between southern Italy and Sicily). Included in Appendix D of this report are tables of the optical depths, visibility, Aitken Nuclei concentration and relative humidity and Elemental Particle Composition from the USS America cruise.

2.0 SUMMARY OF RESULTS

The objective of Calspan's participation was to record the solar intensity, visibility and other meteorological data, and physical characteristics of aerosol from a surface observing platform in the Straits of Gibraltar for subsequent interpretive analyses. Several conclusions and recommendations have resulted from our data analysis efforts.

Possibly the most novel piece of information obtained from our analyses concerns the surface mixed layer depth. It appears that the capping inversion at the top of the marine boundary layer is not always the top of the mixed layer. The top of the mixed layer can be below the inversion base with a decoupled layer existing between the mixed layer and inversion. Several estimates of boundary layer aerosol optical depth were found to agree better with measured aerosol optical depths when the mixed layer depth was used to define the marine boundary layer.

Surface visibility fluctuations were found to correlate with particle concentration in the 0.56 to 1.78 micron diameter range, and the surface relative humidity and elemental composition of the particles controlled to a large extent the concentration in this range. Visibilities of 5 to 10km were associated with particle concentrations of >60 per cc in this size range, 10 to 30km visibility with 20 to 60 particles per cc, and 30-70km visibility with < 20 particles per cc. The lowest visibility occurred on the 18th and the highest on 21-22 June.

3.0 INSTRUMENTATION

Calspan instrumentation deployed aboard the LYNCH and data acquisition parameters are listed in Table 1. Small particle instrumentation (items 1-3 in Table 1) was mounted on benches in the chart room aft of the bridge. Sample air for these instruments was drawn through a two inch (inside diameter), 30 foot long sample tube by a pump. Each instrument's sample pump drew the required amount of air for operation from this supply. Residence time in the two inch tube was approximately 30 seconds.

TABLE 1

CALSPAN INSTRUMENTATION INSTALLED ON THE USNS LYNCH

GIBRALTAR EXPERIMENT PORTION OF WESTERN MEDITERRANEAN CIRCULATION EXPERIMENT JUNE 1986

	Instrument	Parameter	Record Frequency	Number of Observations	Height Above Sea Surface
1.	Gardner Small Particle Detector	Aerosol Concentration (>.0025 μm diameter)	hourly	153	12 meters
2.	Thermo Systems Model 3030 Electrical Aerosol Analyzer	Aerosol Size Distribution (0.01 to 0.562 μm diameter)	hourly	164	12 meters
3.	Royco Model 225 Optical Particle Counter	Aerosol Size Distribution (0.56 to 5.0 μm diameter)	hourly	160	12 meters
4.	HSS Visibility Meter Model VR-301-19	Scattering Coefficient (.4 to 4 x 10^{-5} m^{-1})	continuous	-	12 meters
5.	Calspan Droplet Sampler (gelatin replication)	Drop Size distribution (3-100 μm diameter)	variable	34	12 meters
6.	Sun Photometer (Calspan modified)	Solar intensity (0.502 μm wavelength)	hourly	134	9 meters
7.	Sling Psychrometer	Wet and Dry Bulb Temperatures	hourly	166	9 meters
8.	Casella Cascade Impactors	Individual Particle morphology, composition analyses (>.05 μm diameter)	variable	35	12 meters
9.	Sample System	Provide continuous supply of air to items 1,2,3	-	-	12 meters

The HSS visibility meter was mounted on a railing above the bridge deck on the port side near the sample supply tube inlet. Drop replicates and Casella impactor samples were taken at this level also but as far forward as possible. All sampling locations were chosen to minimize contamination from the ship and bow spray. Meteorological observations, sun photometry and psychrometric data were obtained on the bridge deck. Wind speed and direction were recorded from the ship's wind system, located 20 meters above the sea surface. Ship's position, speed and direction were obtained from the onboard Satellite Navigator and from the LYNCH deck log.

Daily checks of instruments' flow rates and calibration test points were performed and slight adjustments were made when necessary.

Sun photometry data at several wavelengths, sea surface temperature, and meteorological observations were obtained hourly by NEPRF personnel aboard the USNS Lynch. In addition, radiosonde data were obtained at 0800 GMT and 1200 GMT daily during the cruise. These data are not reported here.

The Casella impactor samples were analyzed using scanning electron microscopy for approximate size determination and energy dispersive X-ray analysis of individual particles for elemental composition. Drop replicates were photographed, sized, counted and analyzed via computer routines to provide aqueous particle size spectra at sizes >3 um diameter.

Appendix A and B contain hourly tabulations of observations (reproduced from the data volume), aerosol size spectra from the EAA, Royco and Drop impactor, and aerosol elemental

composition from the Casella impactor.

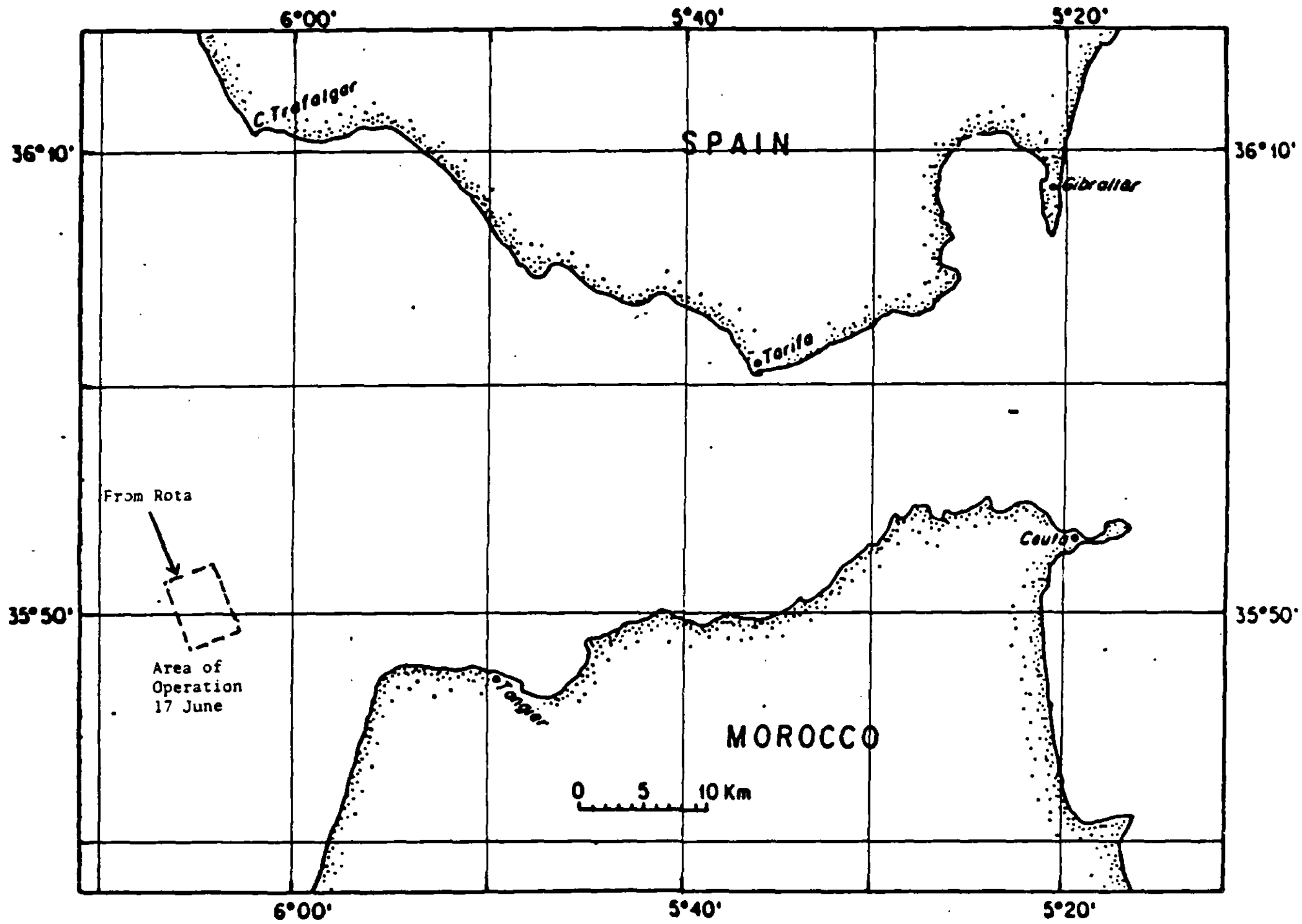
4.0 EXPERIMENTAL PROCEDURE

To provide a complete aerosol characterization of the Straits of Gibraltar region for use in visibility modelling, we obtained aerosol data during daylight hours when visible wavelength satellite imagery would be available. In particular, emphasis was placed on obtaining complete aerosol size spectra (.01 to 100 micron) and aerosol chemistry data between 1000 and 1400 GMT each day to coincide with satellite overpasses.

Upon departure from Rota, Spain, acquisition of meteorological data began immediately. Upon reaching the Straits of Gibraltar, the acquisition of aerosol data began. In general, readings were taken on the hour. Special observations were made to coincide with satellite overpasses or to characterize significant changes in the meteorology or aerosol character of the air mass. Continuous operation of particle sizing instrumentation in the 0.01 to 10 micron range pinpointed changes in the aerosol character of the air mass. Samples acquired with the droplet impactor and Casella impactor characterized any changes in the aerosol character of the air mass in more detail.

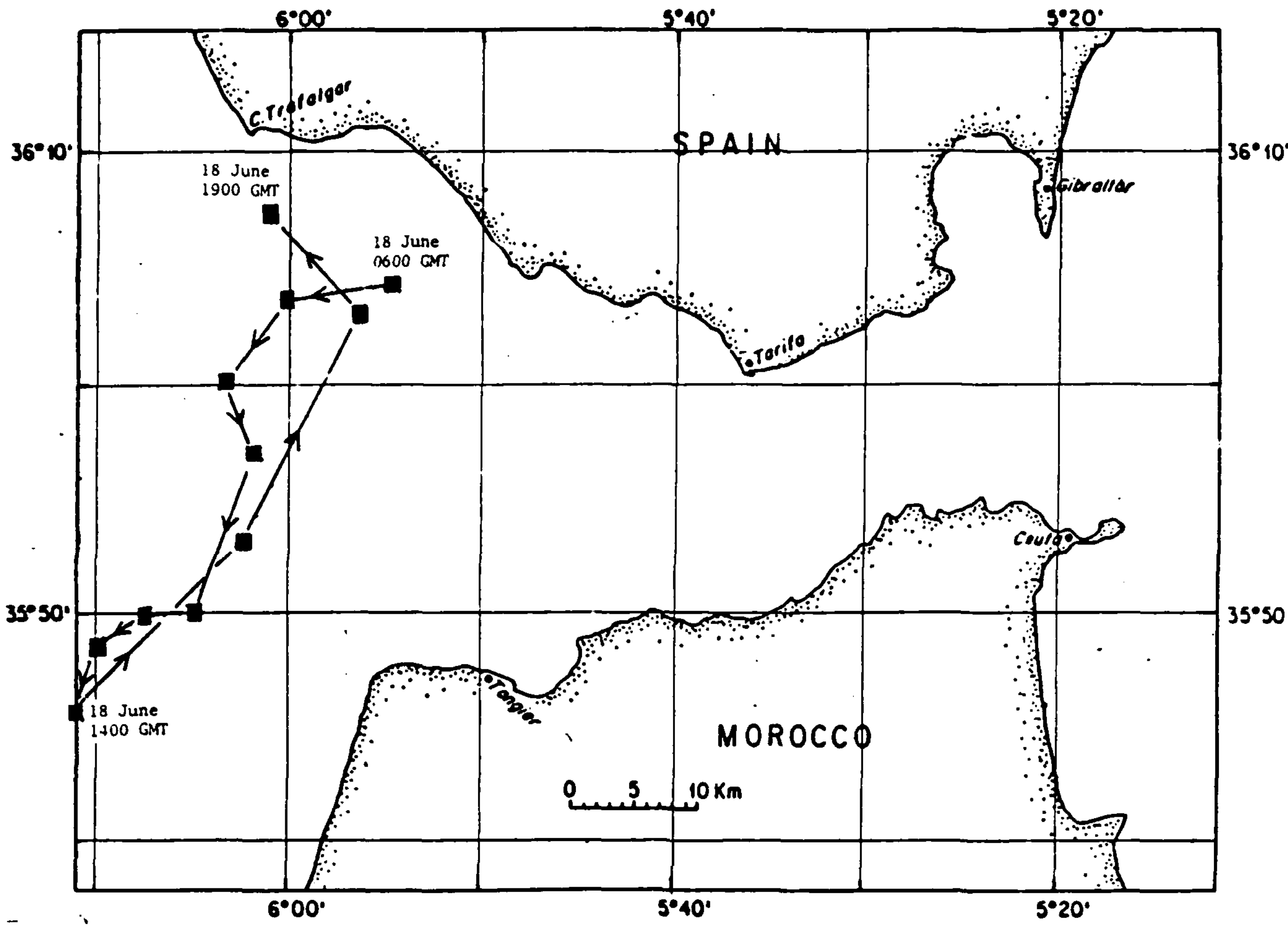
5.0 CRUISE TRACK AND DAILY ACTIVITY SUMMARY

Short summaries of daily activities and discussions of meteorological phenomena observed during the cruise are presented in this section. Each summary is accompanied by a chart of the ship's position and movements for each day of the cruise period. Local daylight time in the operation area of the cruise is GMT + 2 hours. All reference to time in this report is in Greenwich Mean Time (GMT).



17 JUNE

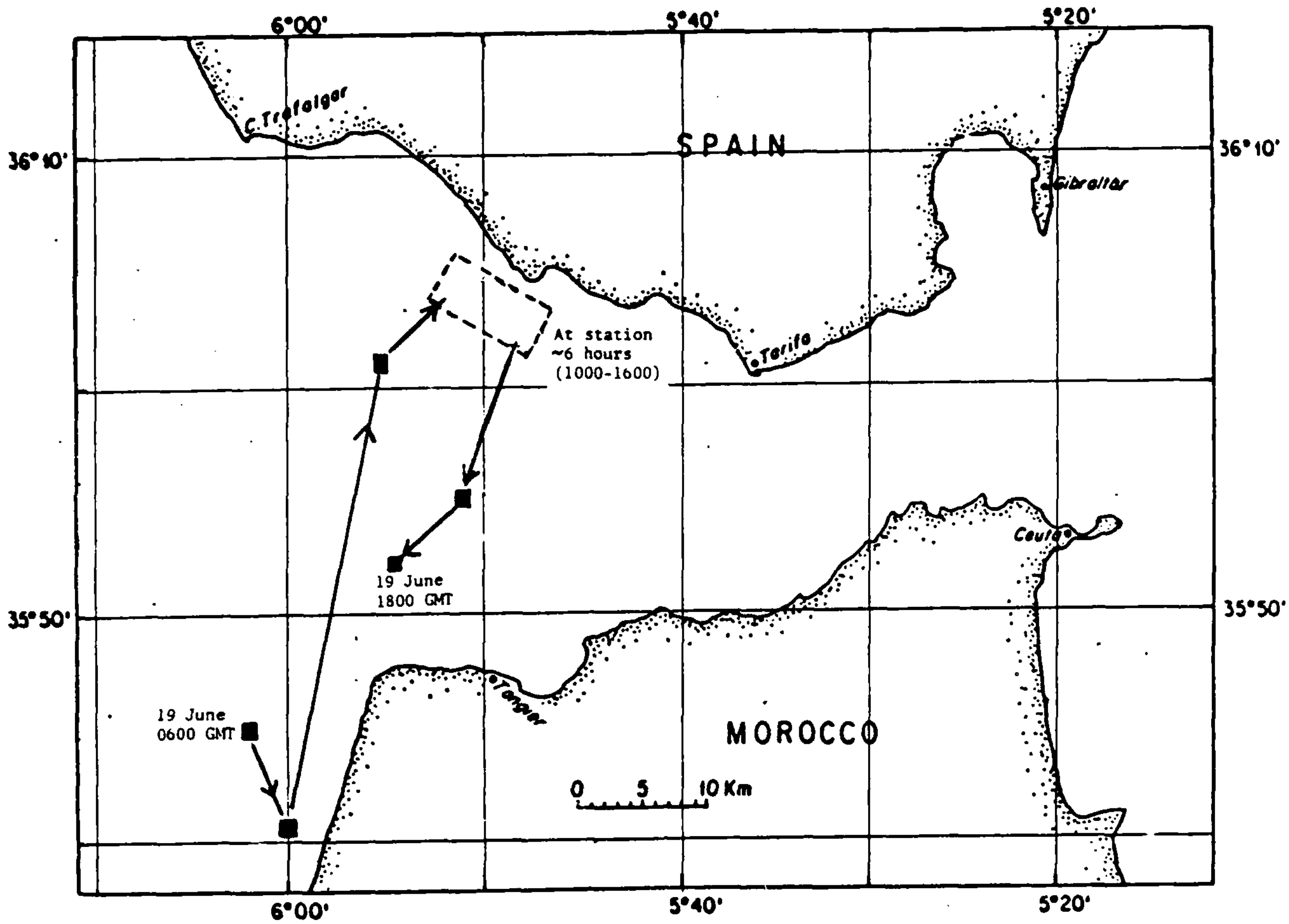
The LYNCH left the pier at Rota, Spain Naval Base at 0742 GMT and cleared the harbor entrance at 0805 GMT. Skies were mostly cloudy with ~4 km visibility in haze. First observations were taken at 1100 GMT, skies were still stratus overcast. By 1200 GMT, cloud cover had reduced to 0.1 thin cirrus. As the LYNCH continued south toward the operation area, cloud cover reduced to 0.1 thin cirrus. We reached first station at 1430 GMT and remained there for the rest of the day. At this location visibilty was 15 - 20 km, cloud cover was 0.1 thin cirrus which increased to 0.7 cirrus by dusk. Observations ended at 1900 GMT.



18 JUNE

During the night, we moved north to a point ~15 kilometers from the Spanish coast. Observations began at 0600 GMT. The ship travelled south along the ~6 degree longitude line all day to a point ~15 km off the Moroccan coast by 1400 GMT. Skies were overcast with cirrus and stratus all day, precluding sun photometry measurements. At 0700 GMT, the wind direction shifted to E/SE and wind speed increased from 2 meters/sec to 7-8 meters/sec with whitecaps becoming more frequent. As we continued south, by 0900 GMT, winds subsided to 1-2 meters/sec and direction shifted to southwesterly. Whitecaps decreased in frequency and visibility improved from 4 km to 10 km. At 1600 GMT, wind direction again shifted to E/SE and speed increased to 6 meters/sec as we headed north to Spanish side of Strait to redo stations along the 6 degree longitude line during the night.

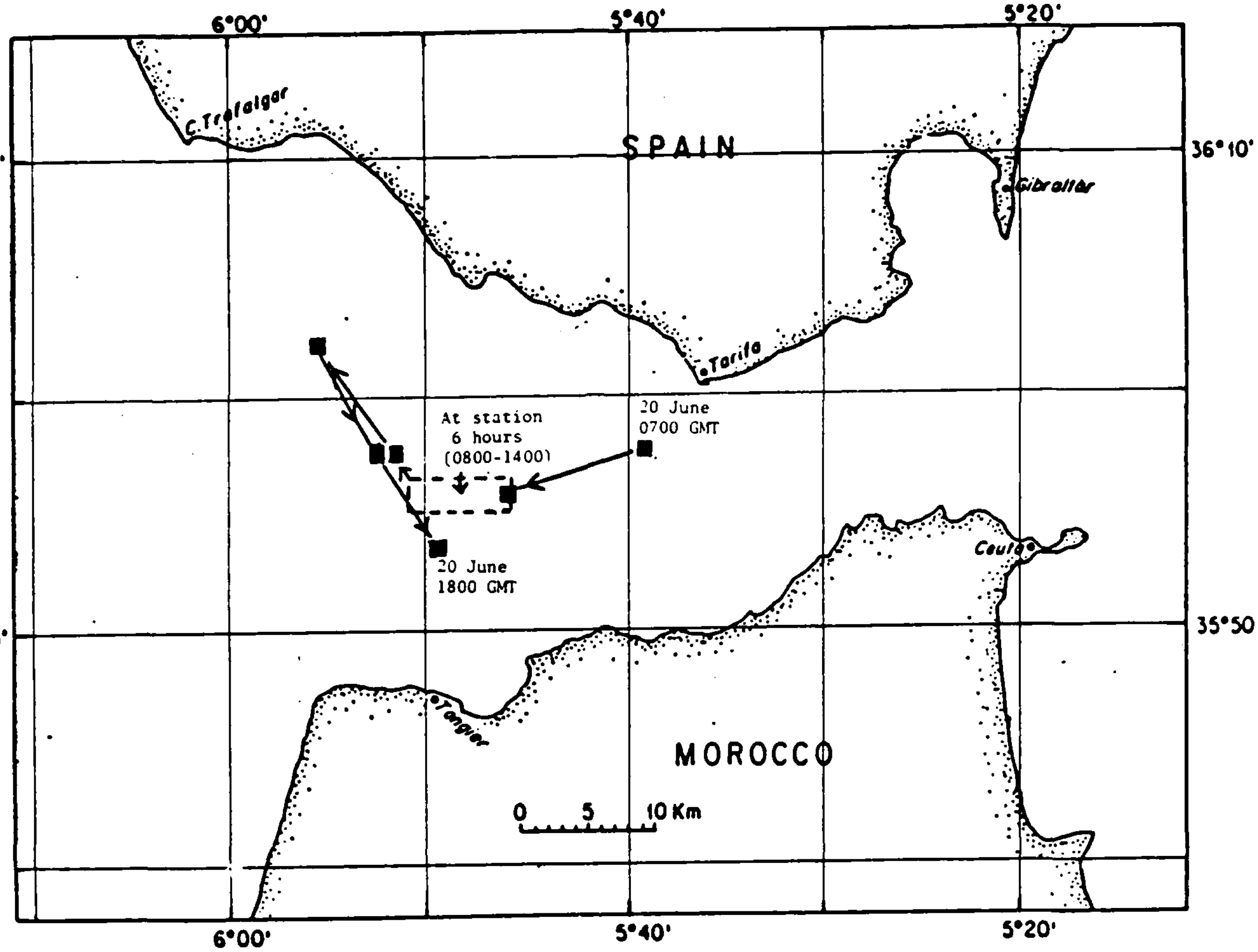
The wind regime in the Strait appears to have been easterly in the north half of the Strait and west to southwest in the south half, with higher wind speeds associated with the easterly flow.



19 JUNE

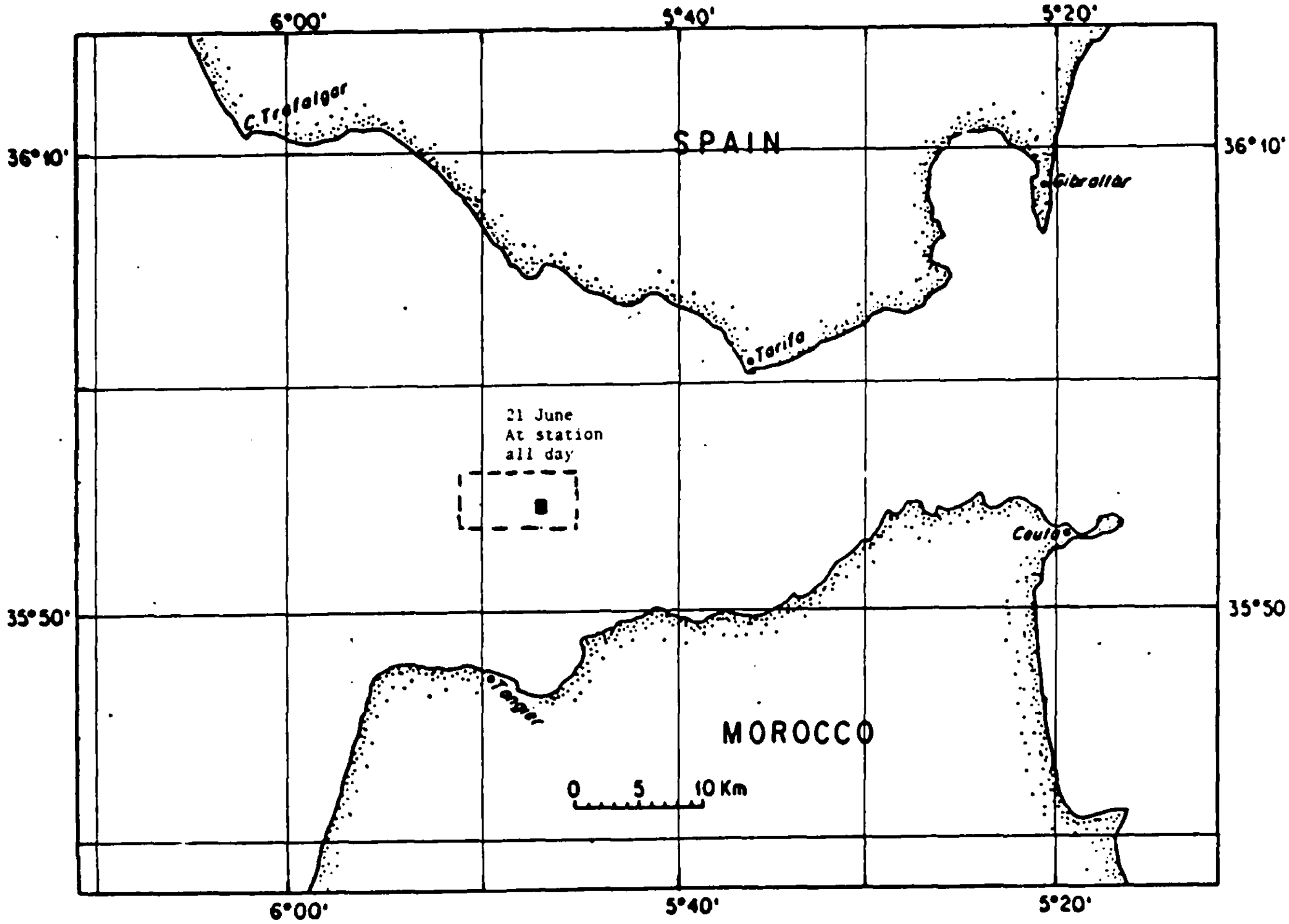
Observations began at 0600 GMT. Our position was ~7 km off the Moroccan coast. At that time, seas were calm, thin cirrus were overhead and visibility was 3 km in haze. We moved north from 700 to 0900 GMT to a position 2-3 km off the Spanish coast. We remained there for 6 hours. During that period, skies were 0.1 cirrus in the east half of the sky, but these did not obstruct the sun. Sun photometry measurements were obtained from 0700 to 1700 GMT. Early in the day (in the southern half of the Straits) winds were ~2 meters/sec with variable direction. Beginning at 1015 (at station off Spain), winds shifted to SE and speed increased to 6-9 meters/sec. Whitecaps formed during this period. By 1400 GMT, the wind direction shifted to W/NW and speeds decreased to 3-4 meters/sec. Drop replicates and Casella samples were taken to document the change in aerosol characteristics associated with each of these wind regimes. Visibility was generally near 20 km in haze with an increase to 27 km after 1400 GMT, associated with the shift to westerly winds. After 1600 GMT, we moved south to a point 10 km NW of Tangier, Morocco.

Major brush fires appeared just inland of the Spanish coast yesterday and today. A significant amount of smoke is output by these fires and may contribute significantly to the aerosol burden over the Straits. On the evening of 18 June, a plume from this fire area was estimated to be ~16 km long and was brown in color and extended in a easterly direction.



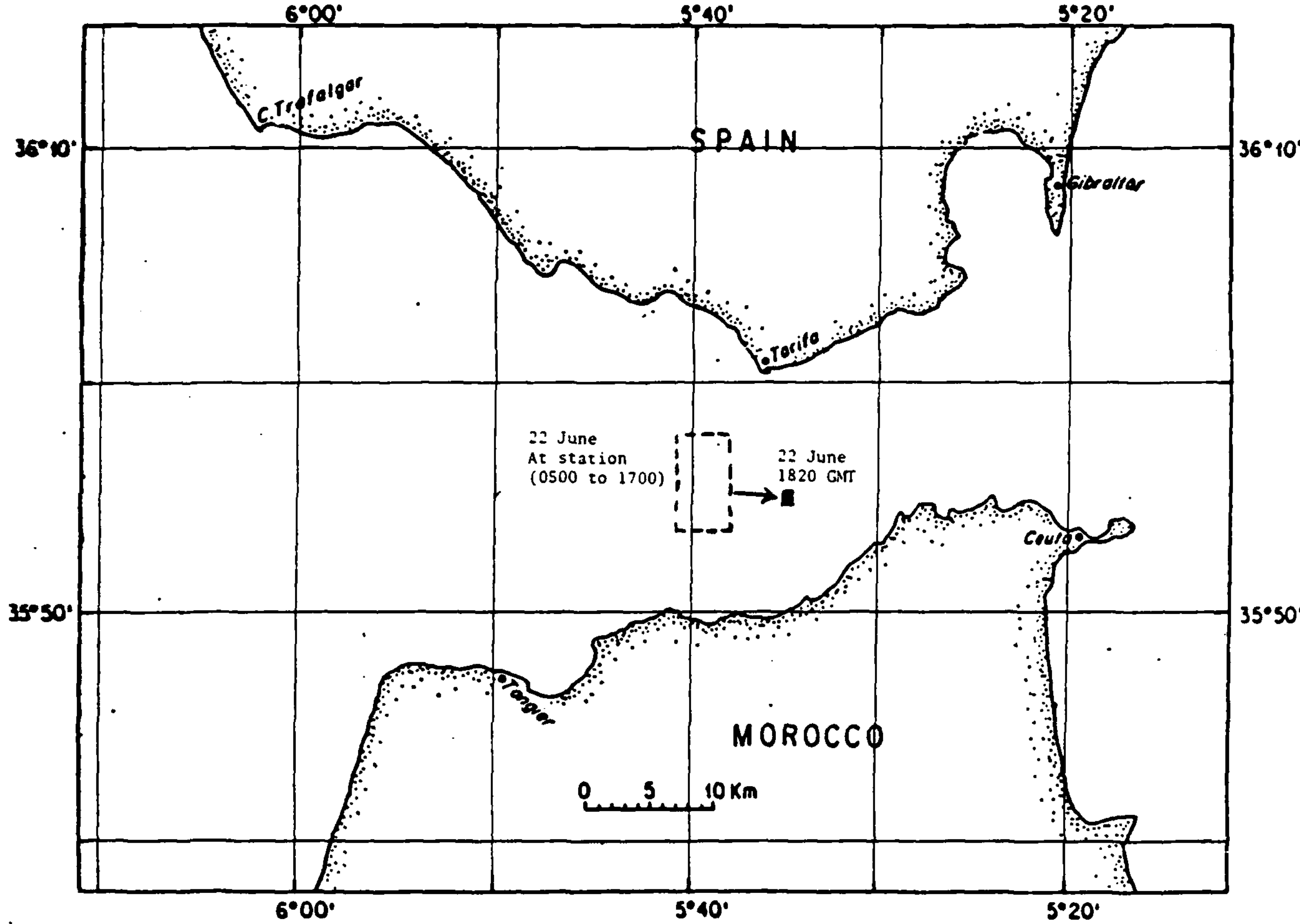
20 JUNE

Operations were conducted in the middle of the Straits, due north of Tangier, Morocco. This day was mostly cloudy with stratus and strato-cumulus. Cloud cover reduced to 0.5 for a brief period in the afternoon, but quickly closed up again. Substantial clearing occurred after 1600 GMT, though too late for peak sun photometry. Winds this day were W to SW before 1000 GMT, but shifted to NW after 1000 GMT, associated with a frontal passage. Visibility increased from 25 km before 1000 GMT to >40 km after, with a particle concentration change from 12,000/cc to 4000/cc heralding an air mass change from mixed/continental to maritime.



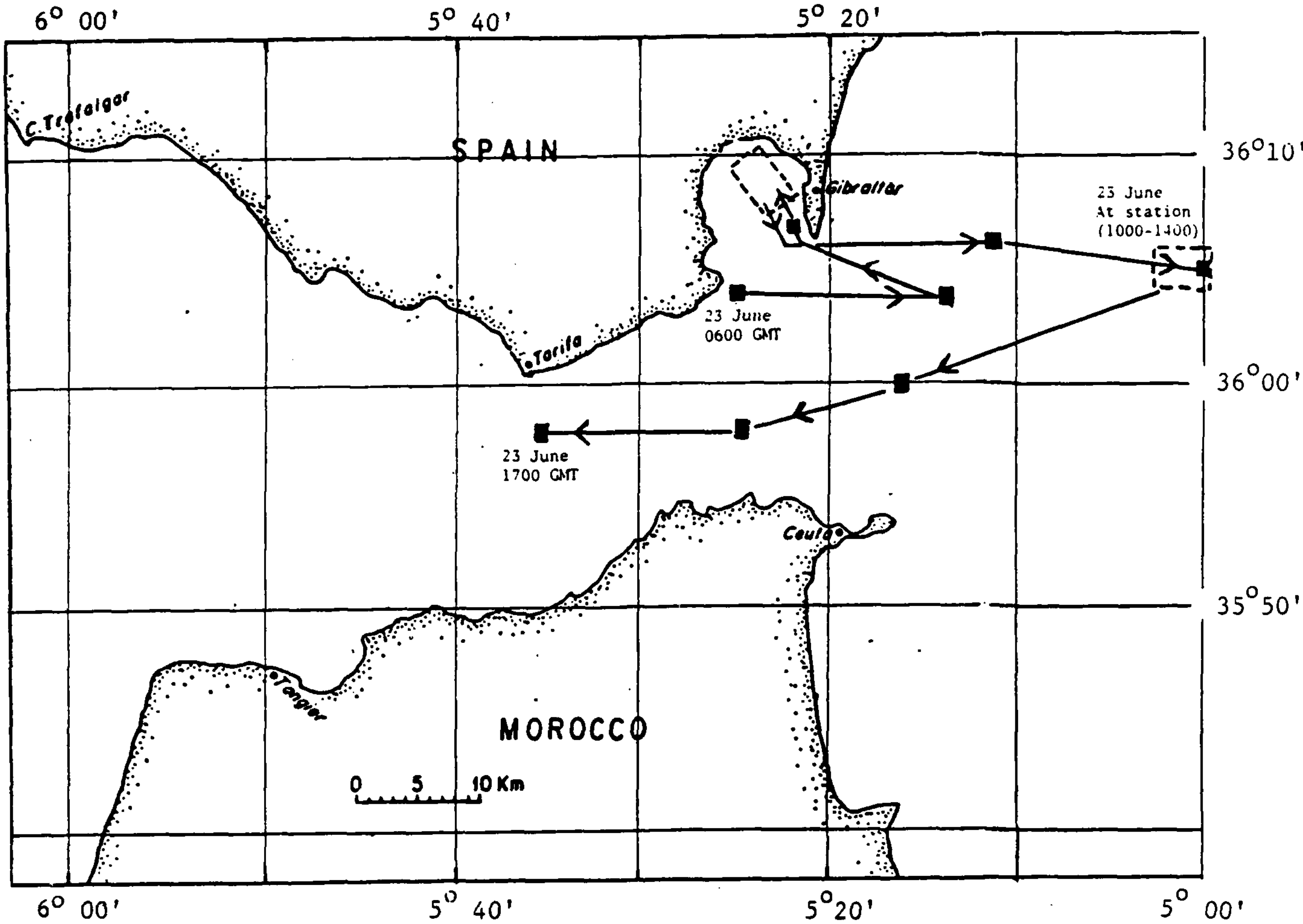
21 JUNE

The ship spent the entire day at station ~15 km north of Tangier, Morocco. Early morning strato-cumulus cloud cover (0.8) reduced to 0.3 strato-cumulus by 1030 GMT (mainly over land). Early morning visibility was~64 km, afternoon visibilites,~80 km. Particle concentrations averaged near 2,000/cc. We were in the air mass behind yesterday's frontal passage. Excellent sun photometry today; no cirrus near sun all day. Few cumulus formed over the hills of Morocco during the afternoon. Northwesterly winds at 5-7 meters/sec blew all day. Suspected photochemical haze became visible over Tangier, Morocco after 1800 GMT, though it did not extend to our location.



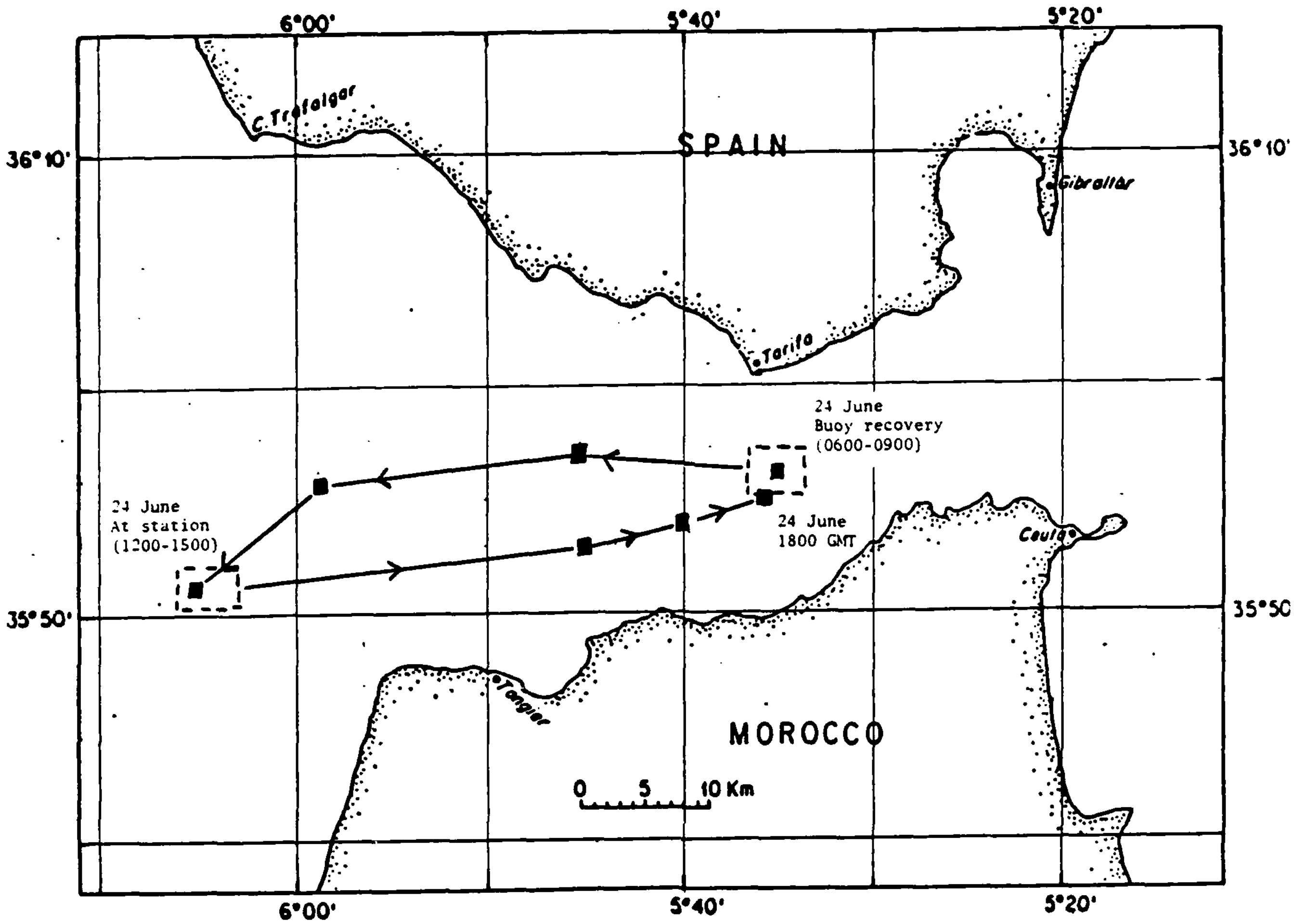
22 JUNE

The entire day was spent at station on the east side of the sill (~10km east of yesterday's position). This day's weather was nearly a duplicate of yesterday's. Cumulus at 0.5 coverage decreased to 0.1 by 0700 GMT and remained that way for the rest of the day. Excellent sun photometry (no cirrus) all day. Particle concentrations were slightly higher today than yesterday but with lower RH. Visibility remained >50 km all day. Winds began northwesterly, shifting to more westerly and southwesterly by afternoon. Wind speeds were fairly steady at 5-7 meters/sec. Small whitecaps formed at 1400 GMT and persisted for the remainder of the day.



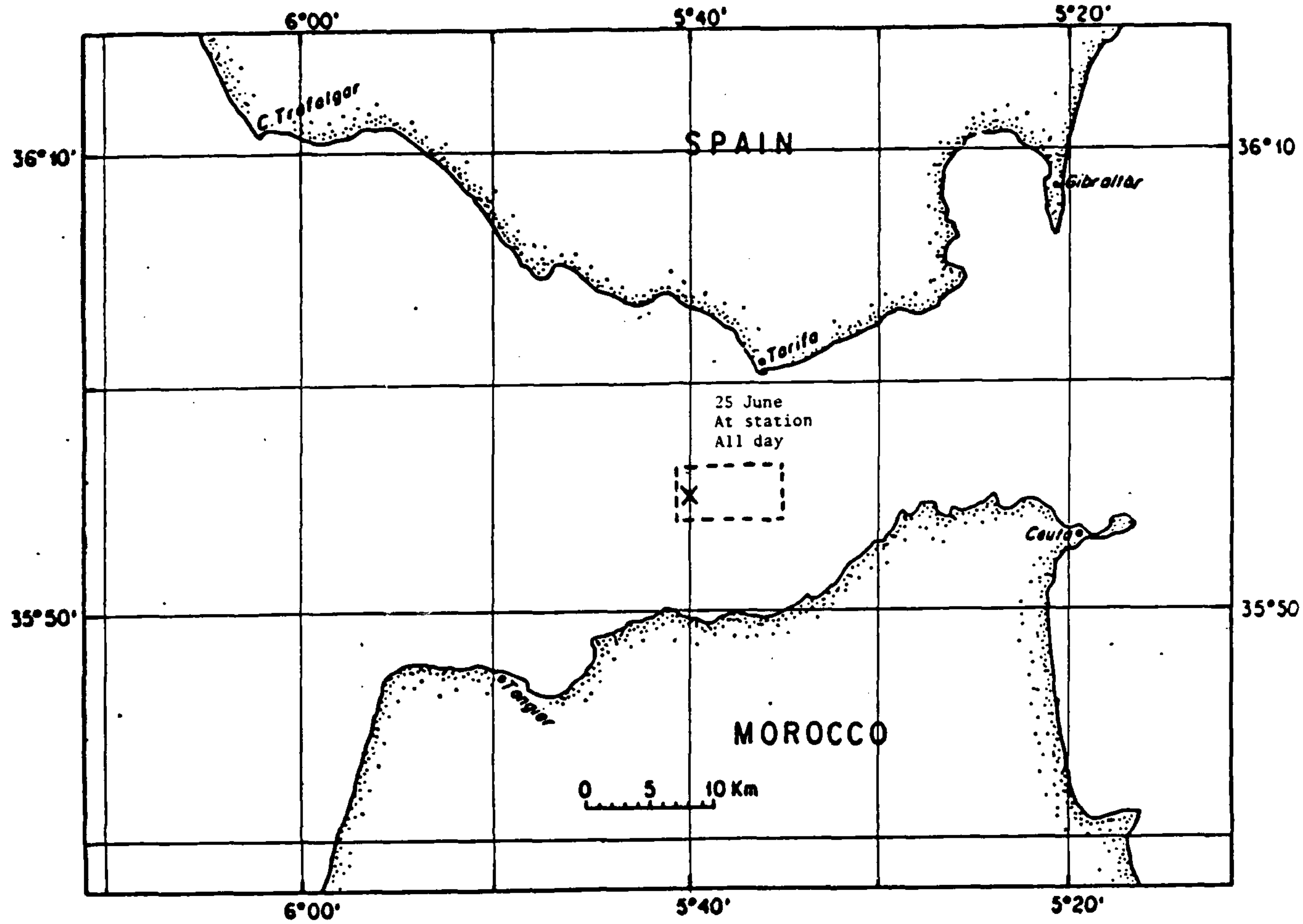
23 JUNE

Overnight, we headed east to Gibraltar harbor. In the early morning we entered the harbor to receive delivery of computer tapes; we then headed east to station in the Mediterranean, ~25km east of Gibraltar, arriving at ~0930 GMT. Skies were clear with strong (9-15 meters/sec) SW winds. Sun photometry was very good today with only a few scattered cumulus in the sky. White-capping was very common while at station. By 1400 GMT, we were heading southwesterly back into the Strait, arriving 6km south of Tarifa by 1700 GMT. During this travel, fires began appearing inland on the Spanish side of the Strait near Gibraltar. Smoke was spreading out over the Mediterranean behind us. Winds continued SW at 6-9 meters/sec, skies remained clear for rest of day.



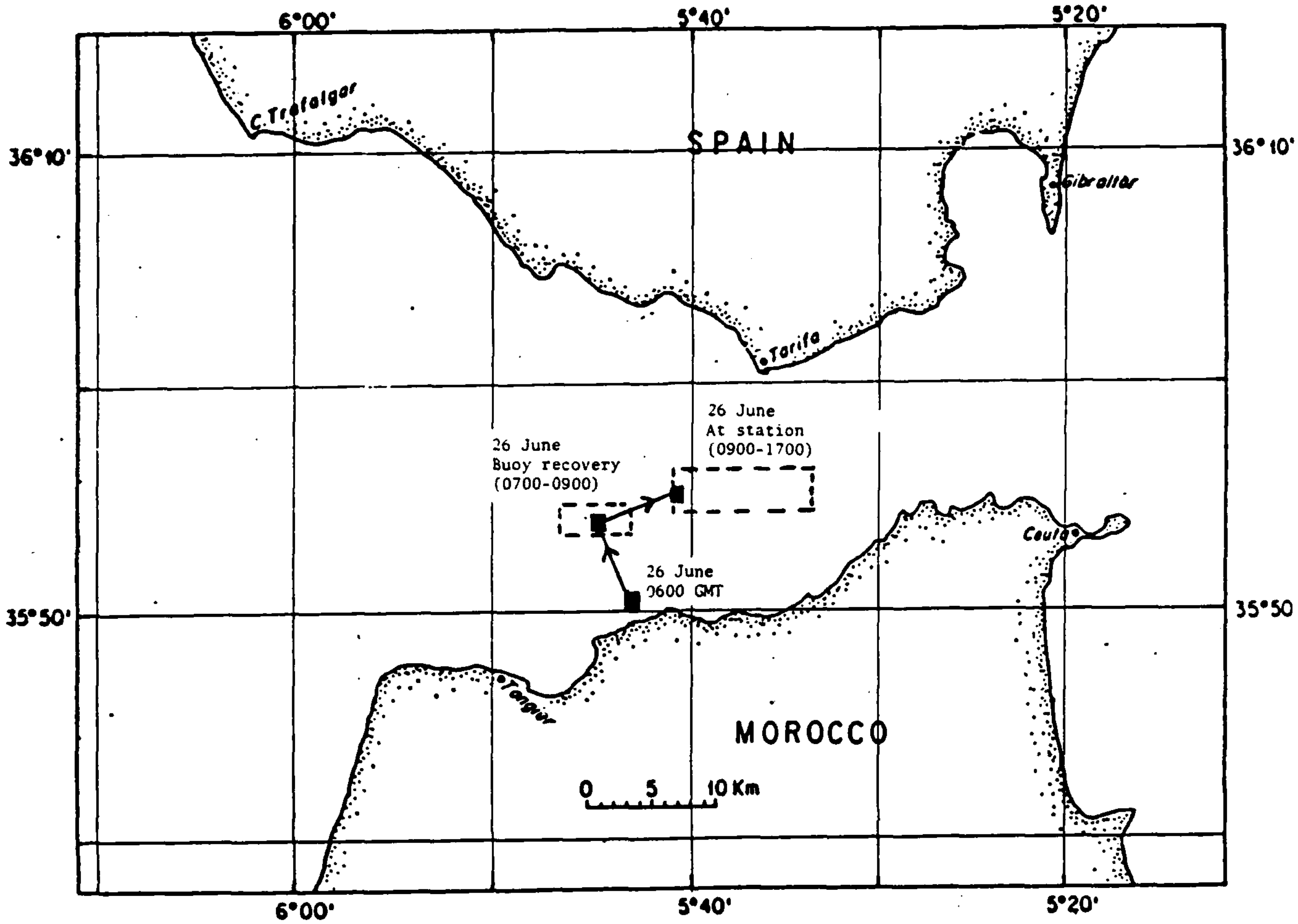
24 JUNE

The cruise track for this day consisted of a westward heading to the first station we worked on 17 June, then a return eastward to our starting point for this day. A fairly dominant cirrus fibratus cloud deck covered 0.3 to 0.6 of the sky throughout the day, reducing the sun's intensity slightly.
High visibilities of the last few days were replaced by ~30 km visibility most of the day. Westerly winds at 5-7 meters/sec continued all day.



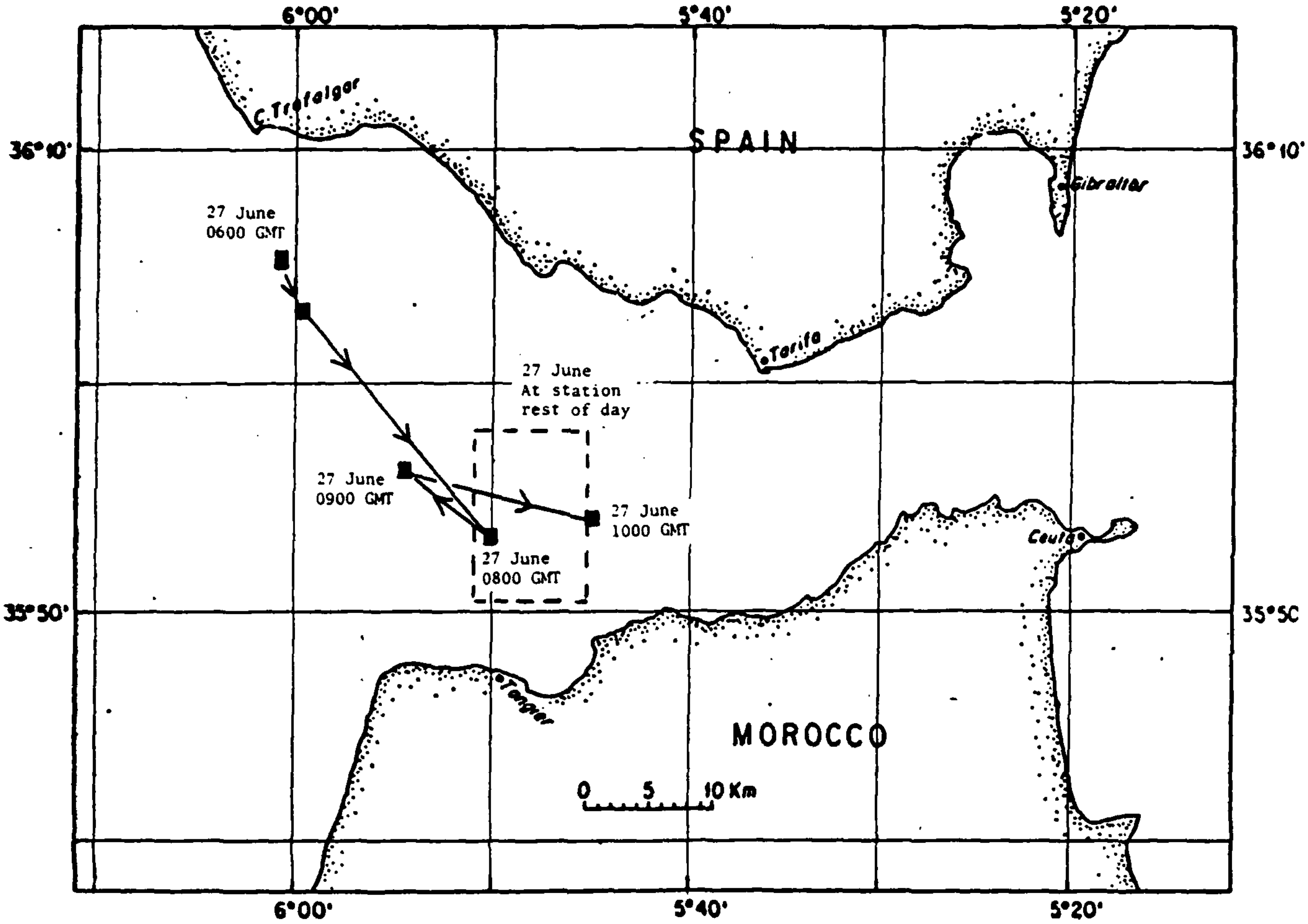
25 JUNE

The entire day was spent at station ~10 km south of Tarifa, Spain. Generally higher relative humidity than past few days (80-90%). Early morning strato-cumulus (0.7) slowly dissipated to 0.1 cumulus over mountains by 1200 GMT. No cirrus today and surface horizontal visibility was quite good (30-50 km), yet peak sun photometer reading was significantly lower than yesterday. It appeared more hazy aloft; visibility when looking on a slant appeared much lower than when looking horizontally. Winds predominantly out of the west to northwest at 2-4 meters/sec blew all day. Seas were fairly calm most of the day, no whitecapping.



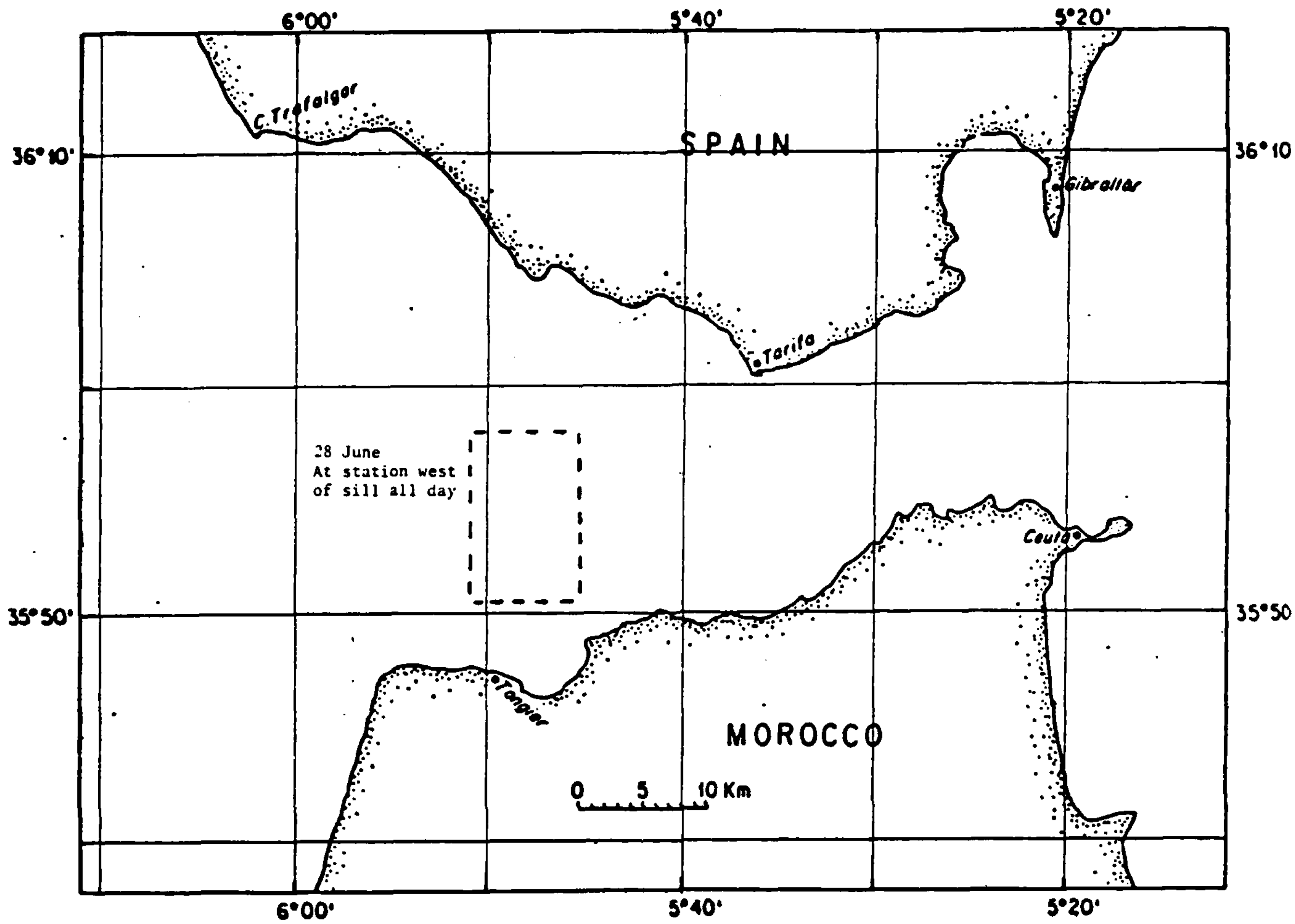
26 JUNE

We began the day ~2km off the Moroccan coast. We travelled northward ~5km and spent 2-3 hours in the early morning locating and retrieving a current meter. After retrieval, we headed NE to yesterday's station position, where we remained for the rest of the day. During retrieval operations, skies were 0.9 strato-cumulus covered. Upon reaching station (0900 GMT), overcast had cleared to 0.2 strato-cumulus. Westerly winds at 5-6 meters/sec continued all day, producing a few whitecaps. From 1100 to 1500 GMT, skies were clear with no cirrus. Maximum sun photometer reading was at 1200 GMT. Particle concentrations were low (1000 to 1500 per cc); relative humidity was near 80%.



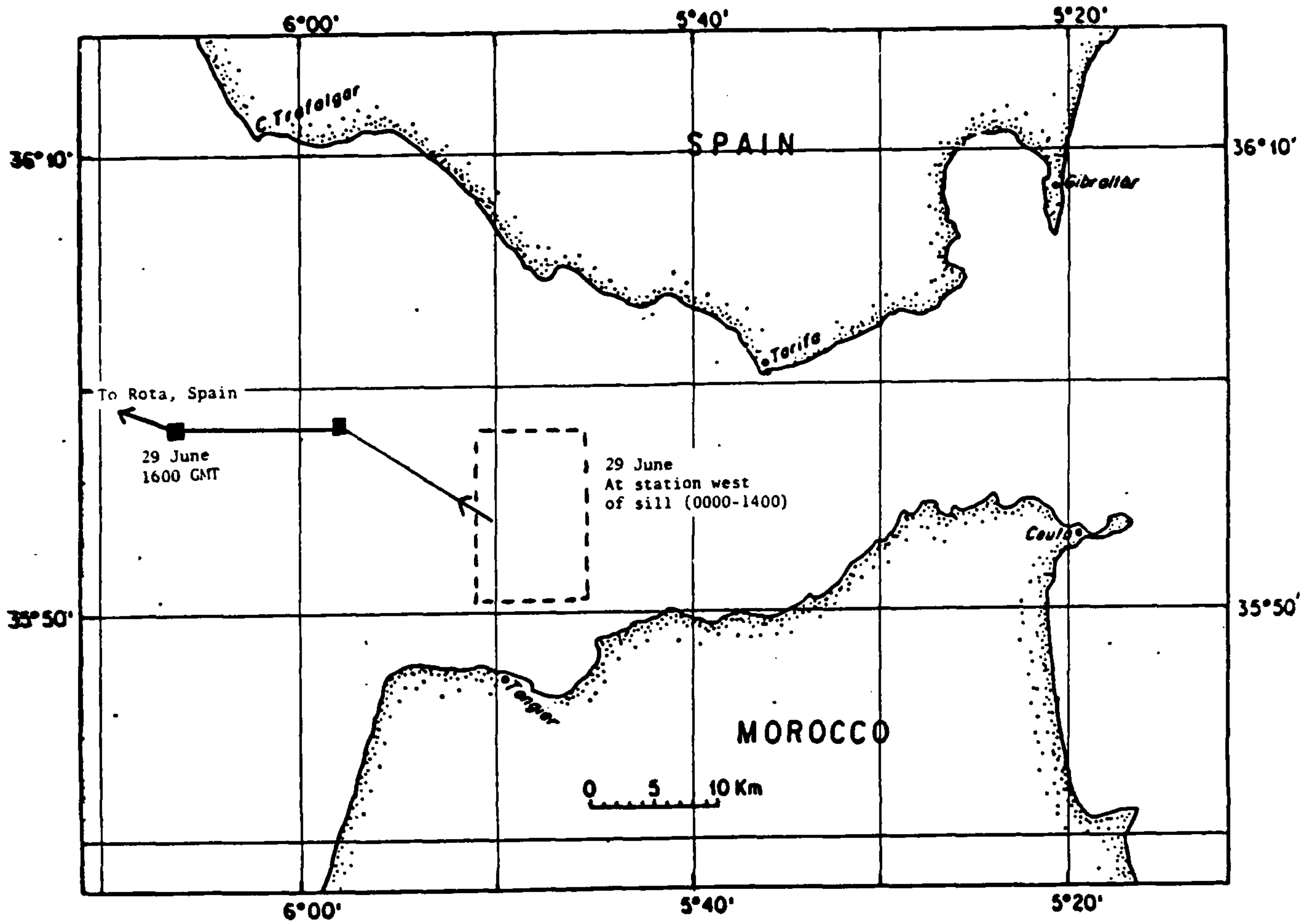
27 JUNE

During the night we moved out of the main shipping lane to a point ~10km off of the Spanish coast (near Cape Trafalgar). By 1000 GMT we were at station on the west side of the inner sill, to spend 48 hours in this location. The day began with a 0.8 broken stratus deck in all sky quadrants. By 0900 GMT, as we approached station, this cloud deck had reduced to 0.1 mainly over land. Rest of day's weather was clear with some haze and a few small whitecaps (from 0900 GMT until observations ended at 1800 GMT). Winds were northwesterly all day, bringing maritime air into the Straits. Relative humidity was in the low to mid 80%'s most of the day.



28 JUNE

Continued operation west of inner sill all day. Began the day under a southwesterly flow with visibility near 19 to 23 km and 0.3 strato-cumulus cloud cover. At 1200 GMT, visibility increased to 37km, relative humidity dropped from the mid 80%'s to the mid 70%'s, wind shifted to a WNW direction, and skies became clear. Early morning aerosol may have some continental influence evidert, afternoon air is more maritime in nature. Photochemical smog (yellowish-green haze layer) formed along the coast, over and downwind of Tangier, Morocco; did not appear to extend out to our location.



29 JUNE

We operated at west of sill site until 1400 GMT, then began overnight return to Rota, Spain. A few early morning stratus clouds gave way to brilliantly clear skies in the afternoon. Similar to yesterday, prior to 0900 GMT, winds were southwesterly with 0.3 strato-cumulus and visibility of 15-20 km. Concurrent with a wind shift to WNW at 0900 GMT, visibility improved to ~50 km and RH decreased. Wind direction remained northwesterly throughout the remainder of the day and RH was in the mid 60%'s.

Observations ended at 1600 GMT, 29 June. Equipment teardown began at that time. We arrived in port (Rota) the following morning at 0900 GMT, 30 June 1986.

6.0 DISCUSSION OF RESULTS

6.1 Overview of Visibility Conditions

Hourly ship positions presented in the previous section show that, in general, the ship remained in the Straits of Gibraltar for the duration of the experiment. Early in the experiment, north/south transects of the Straits were made, followed by several days at station just south of Tarifa, Spain. East/west transects through the Straits dominated the latter half of the cruise.

An overview of the visibility conditions encountered during the WMCE field trip is presented in Fig. 1 , which contains the time history of visibility, aerosol concentration in the 0.562-1.78 um diameter size range and relative humidity (RH). The plotted values are the 1200GMT observations for each day.

The visibility was near or above 50km for three periods, 20-22 June, 25-26 June and 29 June; visibility was near 40km for one period, the 28th; visibility was around 30km for two periods, 23-24 June and 27 June; and visibility was in the 10-20km range for the remaining period, 18-19 June. The visibilites encountered on the WMCE field trip thus spanned a wide range of conditions. Very low visibilities (<2km) were not encountered during the experiment period in this region.

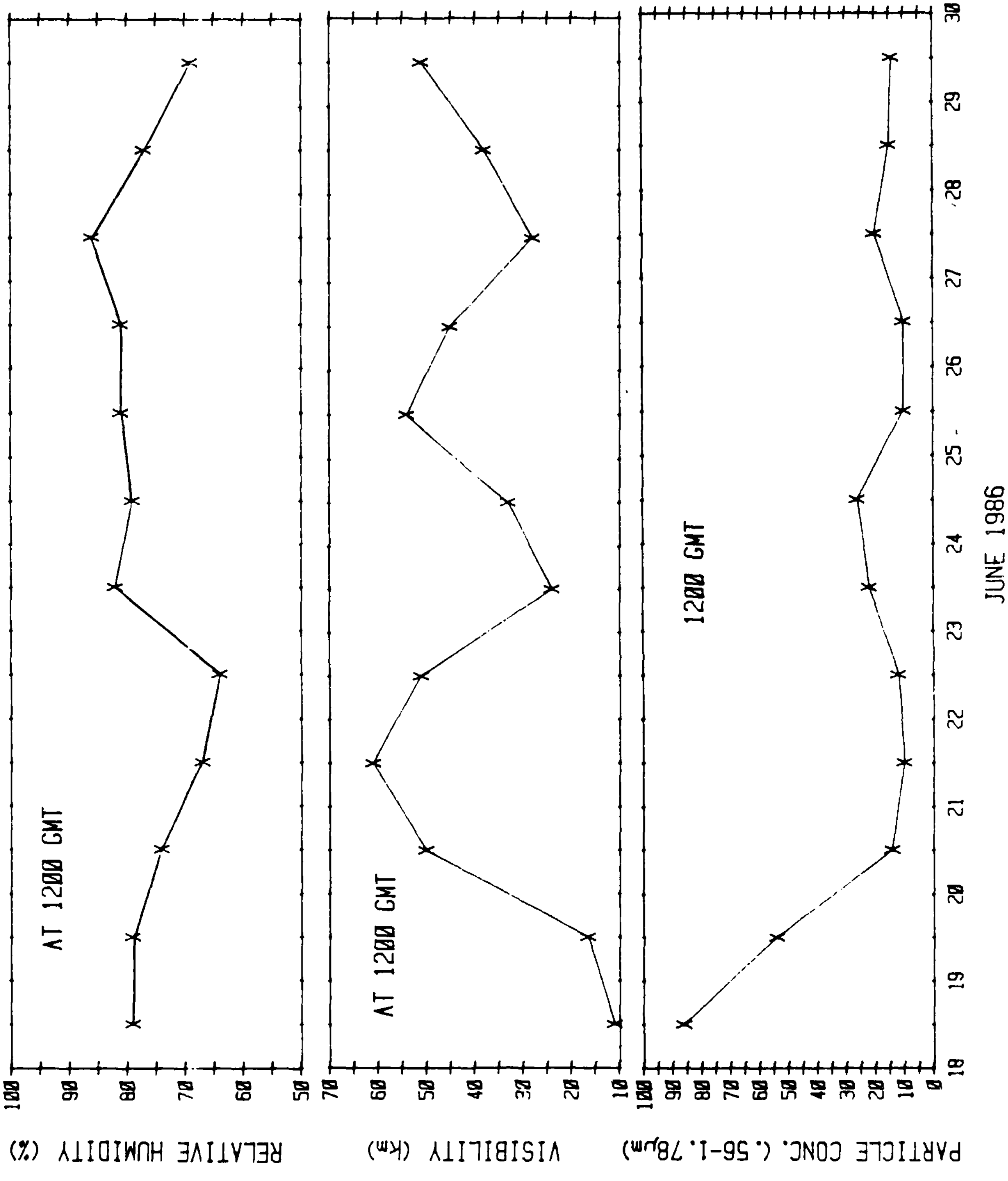


Figure 1. Time history of Relative Humidity, Visibility and Particle Concentration (0.56 to 1.78 micron) for the LYNCH cruise. Values plotted are for 1200 GMT.

6.2 Optical Depth

Aerosol optical depth provides an indication of the general level of atmospheric aerosol burden. Since much of the atmospheric aerosol is located in the planetary boundary layer in the Straits of Gibraltar at this time of year, the aerosol optical depth is also a measure of aerosol burden in the boundary layer. This information can also be used as an indication of the relative day by day aerosol content for characterizing the relative "cleaness" of the air.

6.2.1 Definition Of Optical Depth

Optical depth is defined as

$$1.)\quad \tau_\lambda = \int_0^H \beta(\lambda, z)\, dz$$

where β is the volume extinction coefficient, λ wavelength of radiation and the integral is for the pathlength, H, over which the optical depth applies. Our measurments are concerned with optical depths over the entire depth of the atmosphere at wavelengths primarily in the visible portion of the spectrum.

In particular, we measure solar radiation over a 5 nanometer (nm) band pass centered at 502 nm. At this wavelength, solar radiation passing from the top of the atmosphere down to the earth's surface is affected not only by aerosols but also by Rayleigh scattering and absorption by ozone. The reduction in solar radiation at the earth's surface from these latter two

effects can be accounted for and the aerosol optical depth can be computed from the measurement of solar radiation at the surface and the value of solar radiation at the top of the atmosphere. The measurement technique and computation procedure are found in Appendix C. A tabular listing of the optical depths for the WMCE cruise aboard the USNS Lynch and USS America are found in Appendices A and D, respectively. Optical depth data from the USNS Lynch will be discussed in this report.

6.2.2 Overview of Measured Aerosol Optical Depth

Sun photometer readings were taken every hour on the hour from 0800 to 1800 GMT, cloud cover permitting. The period 19- 29 June provided good sun photometer measurements except for the 20th, and 24th when cloud cover intervened. Experience gained on past field programs has shown that measurment errors are minimized for the few hours centered around noon, and this set of optical depths exhibits the least scatter. In addition, since the technique is sensitive to low solar elevation angles, optical depth values computed from solar radiation measured in early morning and late afternoon appear large compared to those computed during midday. For these reasons, the average optical depth for midday (1000-1400 local time) is used in the following analyses and discussions of optical depth.

Fig. 2 shows a plot of average optical depth versus days, accompanied by visibility and number of particles in the 0.562-1.78 um diameter interval. This figure is a repeat of Fig. 1 with optical depth appearing in place of relative humidity. Recall (Cf. pg. 20) that the peak in visibility during the 20th-22nd was assocaited with relative humidity below 70%

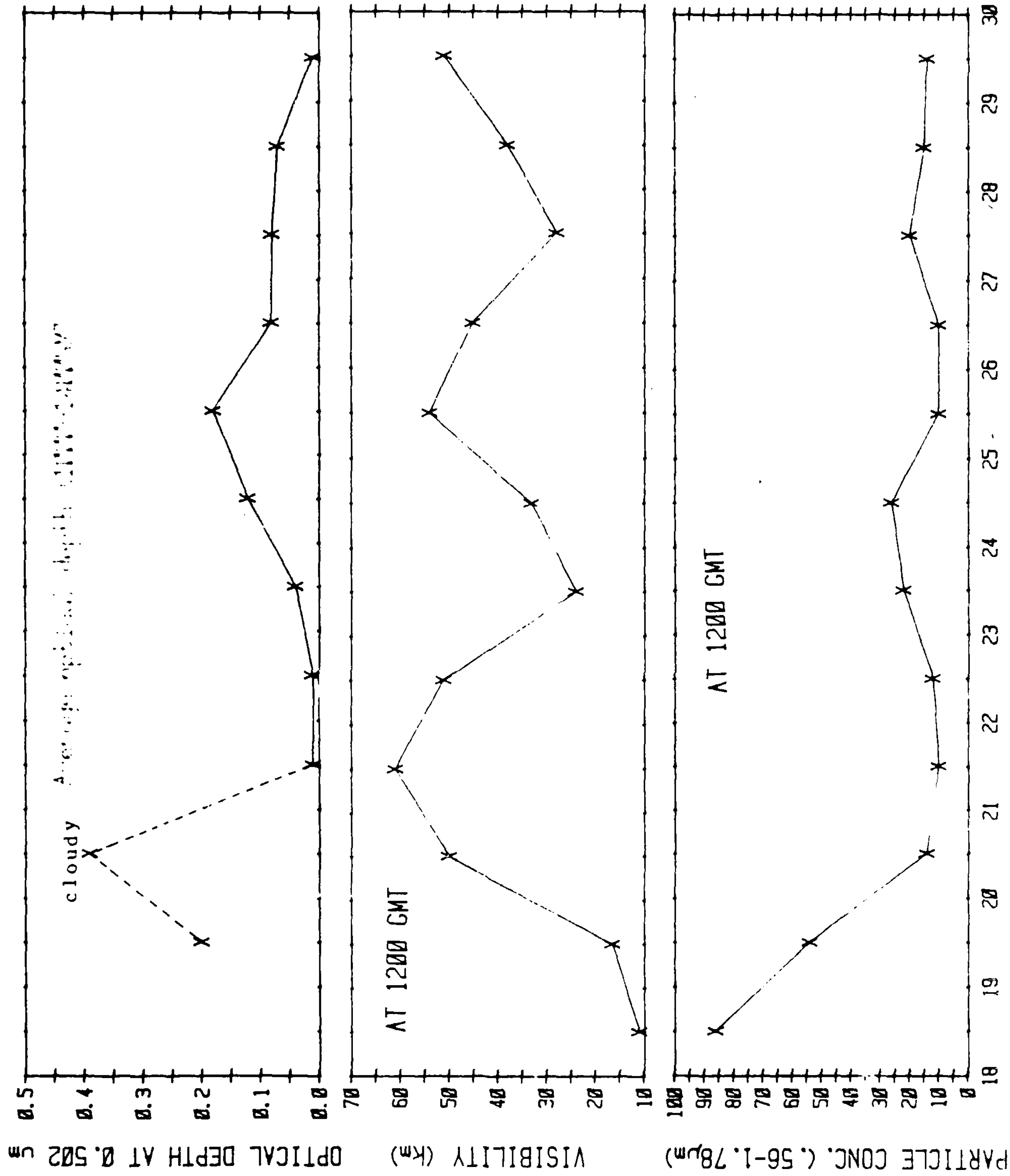


Figure 2. Time history of Optical Depth, Visibility and Particle Concentration (0.56 to 1.78 micron) for the LYNCH cruise. Values plotted are for 1200 GMT.

and the peak on the 25th with relative humidity of ~80% and low winds speeds and few sea salt particles.

In general, the optical depth values vary as expected with the surface visibility. The lowest optical depth values, <.025, occured on 21, 22, 23, and 29 June and are associated with two periods of high visibility (>50km), low particle count, and low relative humidity (70%). The medium values (~0.10) on the 27th and 28th are associated with surface visibility in the 30-40km range. Finally, the largest optical depth of 0.20 is associated with the lowest surface visibility, 15km, observed on the 19th.

6.3 MIXED LAYER DEPTH INFLUENCE ON OPTICAL PROPERTIES

The marine boundary layer is generally considered a well-mixed layer extending from the ocean surface to a capping temperature inversion. Recent published research in scientific journals has discussed certain situations, primarily in the presence of stratocumulus clouds, when the marine boundary layer can be decoupled into two layers, a lower well-mixed Eckman layer and an upper cloud layer. From the WMCE optical depth data, we have found that several estimates of optical depth compared more favorably with the observed values when the well-mixed Eckman layer depth, as opposed to the boundary layer depth defined by the base of the temperature inversion, was used determine the estimates.

The occurrence of this phenomena in the marine boundary layer may have serious implications in attempts to model the optical and other properties of the marine atmosphere. The height to which surface aerosols are mixed determines the amount of

dilution that occurs, and the surface moisture mixing height determines the boundary layer's relative humidity profile, influencing the extent of aerosol growth and the amount of related light scattering. This also has a role in the formation and existence of clouds in the marine boundary layer.

6.3.1 TECHNICAL BACKGROUND

Recent investigations by Telford and Wagner (1981), Nicholls, et al (1983), Nicholls (1984), Rogers, et al (1985), Rogers, et al (1986), Nicholls and Leighton (1986), have produced extensive evidence that the cloud layer is frequently decoupled from the sub-cloud, mixed layer.

Rogers, et al (1985), attribute the decoupling of the cloud and subcould layers to entrainment of warm, very dry air at the cloud top. Nicholls (1984) recognizes the influence of entrainment but also establishes the importance of other cloud related phenomena in decoupling the two layers, such as cloud verti motion driven primarily by long wave radiation and clou ater precipitation at all levels.

The existence of the two isolated layers can be detected from conventional profile data. A typical example of atmospheric profiles under these conditions in the North Sea is given by Nicholls (1983); similar profiles have been presented by Rogers, et al (1985). The most prominent features used in identifying the top of the mixed layer are the small change in mixing ratio (Q) at the top of the mixed layer and a reduction in turbulence intensity at that level. A reduction in equivalent potential temperature above this level from the constant value below this level may be observed, though it is more difficult to discern.

6.3.2 Optical Depth - Estimated vs. Measured

Beginning with a 1982 field program at Valkaria, FL, Calspan has attempted to relate total atmospheric aerosol optical depth (calculated from sun photometer data) to surface mixed layer aerosol optical depth as a way to utilize satellite observations to estimate surface visibility. An estimate of the surface mixed layer aerosol optical depth is computed by estimating the extinction coefficient profile within the boundary layer via the measured surface extinction coefficient and the relative humidity profile in the boundary layer. For these studies, we have assumed that the boundary layer is well mixed so that surface aerosols change size as relative humidity varies. Initially, we have defined the top of the well mixed layer as the level at which the base of the temperature inversion exists. Figure 3 shows the plot of the two parameters for a range of geographical locations, with the points lying reasonably close to the 1:1 line.

From data obtained during this cruise, two WMCE data points, labeled W21 and W22, respectively, demonstrate the effect of using the mixed layer depth (discussed above) instead of the depth of the layer from the surface to the temperature inversion base in the estimation procedure. The X-points labeled (1) and (2) represent the data points obtained when the top of the well mixed boundary layer was defined by the temperature inversion base height. These depths were 1600m for (1) and 1250m for (2) and the corresponding estimated boundary layer aerosol optical depths were 2.5 to 3.0 times larger than the calculated atmospheric optical depths from sun photometer readings.

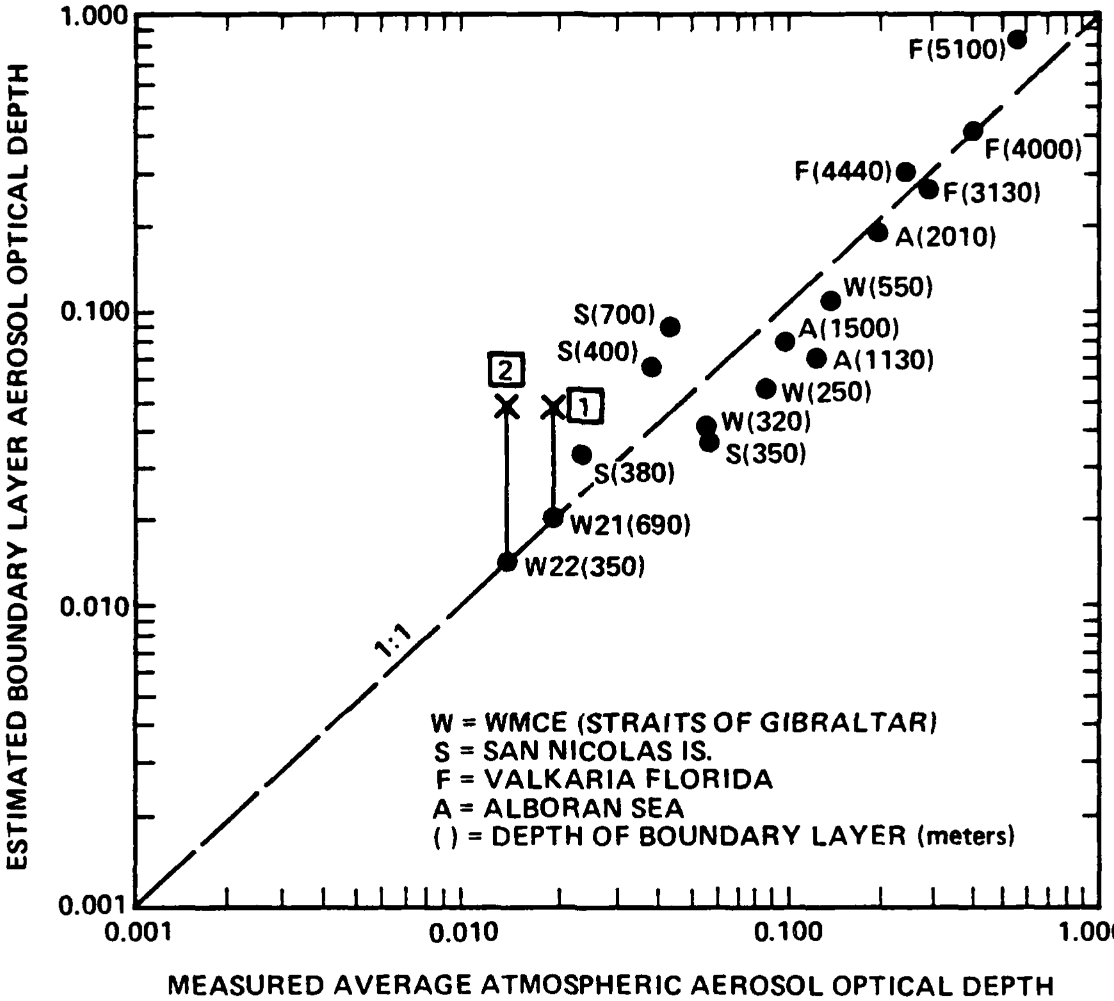


Figure 3. Measured versus Estimated Aerosol Optical Depth for several geographical locations. WMCE data points are shown as W21 and W22.

Examination of the mixing ratio profiles for these two cases showed that a discontinuity occurred in the vertical gradient of the mixing ratio characterized by a slow decrease changing to a rapid decrease. Identifying the slow decrease with the surface mixed layer, the top of the surface based well mixed boundary layer was defined as the height of the discontinuity in the vertical gradient of the mixing ratio. The surface mixed layer optical depth was recomputed on the basis of the newly defined mixed layer depth. The revised data points lying near the 1:1 line resulted from estimating the boundary layer aerosol optical depth for these shallower, surface mixed layers.

It appears that significant improvements in modeling the optical properties of the clear boundary layer could result by incorporating data on the depth of the surface mixed layer defined by the change in mixing ratio when appropriate. Knowing when to apply this rule needs much investigation.

6.4 Relationship Of Visibility To Aerosol Concentration

A discussion of the day to day realization of the relation between visibility and the aerosol concentration in the .56 to 1.78 micron diameter size range is presented here.

For this discussion, we consider only the 1200GMT observations. Diurnal variations of visibility and aerosol concentration, driven primarily by changes in RH, cannot be discussed here because our data set was obtained during daylight hours only.

Our purpose is to provide an integrated description of the interrelationship between the aerosol physics and the meteorological conditions so that a framework from which to

assess the atmosphere's role in producing the aerosol size spectrum is provided.

The data, and their source, on which the discussions are based are listed below:

1.) METEOROLOGICAL DATA

a.) Surface wind velocity and relative humidity from Calspan's WMCE data volume -- Appendix A

b.) Surface weather maps and radiosondes supplied by NEPRF(not shown).

2.) AEROSOL DATA

a.) total nuclei count (Aitken count)--Appendix A

b.) aerosol concentrations -- Appendix B

c.) aerosol chemical composition--Appendix B

The relative humidity averaged near 80%, except for two periods of RH below 70% which coincided with two of the three periods of visibility near 50km. The lower RH periods occurred with a strong influx of air into the Straits of Gibraltar from the eastern Atlantic, a condition which was produced by strong ridging over the Iberian Peninsula accompanied by vigorous low pressure centered off the northwest tip of Spain. Interestingly, this ridging from the ocean to the land is similar to the surface pressure pattern which accompanies similar intrusions of Pacific air into southern California.

The periods of 80% RH were associated with relatively weak surface pressure gradients in the Straits region produced by a thermal low over central Spain and accompanying east-west pressure gradient off the Portugal coast. This surface pressure pattern is very similar to that found over southern California

and the offshore waters during the summer season.

The relationship of visibility to particle concentration in the 0.56 to 1.78 micron diameter size range (hereby referred to as the 1 micron size) is presented in Fig. 4 . The relationships between this particle concentration and the nuclei concentration, the nuclei chemistry and the meteorology of the individual days is now discussed using Fig. 4 as the reference point.

6.4.1 High Visibility and Low Relative Humidity

For two periods, 20-22 June and 28-29 June, visibilities were in the 40-50 km range and particle concentration in the 1 micron diameter size range was between 10 and 15 cm^{-3}. These periods were associated with the two excursions of low RH air, arriving from the Atlantic on predominantly northwesterly winds. The low relative humidity inhibited the growth of aerosols into the 1 um diameter range, particularly NaCl nuclei with their 75% deliquescence threshold humidity.

6.4.2 High Visibility, High RH and Low Nuclei Count

The relatively high visibilities and low 1 um aerosol concentrations on 25-26 June, even with RH near 80%, reflect the effect of low nuclei concentrations on the visibility. On the 25th, the Aitken nuclei concentration of 2500 cm^{-3} was characteristic of (generally speaking) moderately aerosol-laden oceanic air, suggesting moderate visibilities (20-30km). However, the aerosol chemistry data indicated that sea salt was not present in large amounts, which was consistent with the low wind speeds (3m sec^{-1}) and reduction of white caps and ejection of sea salt nuclei into the air. Meteorologically, the 25th represents the height of quasi-stagnant conditions, with a

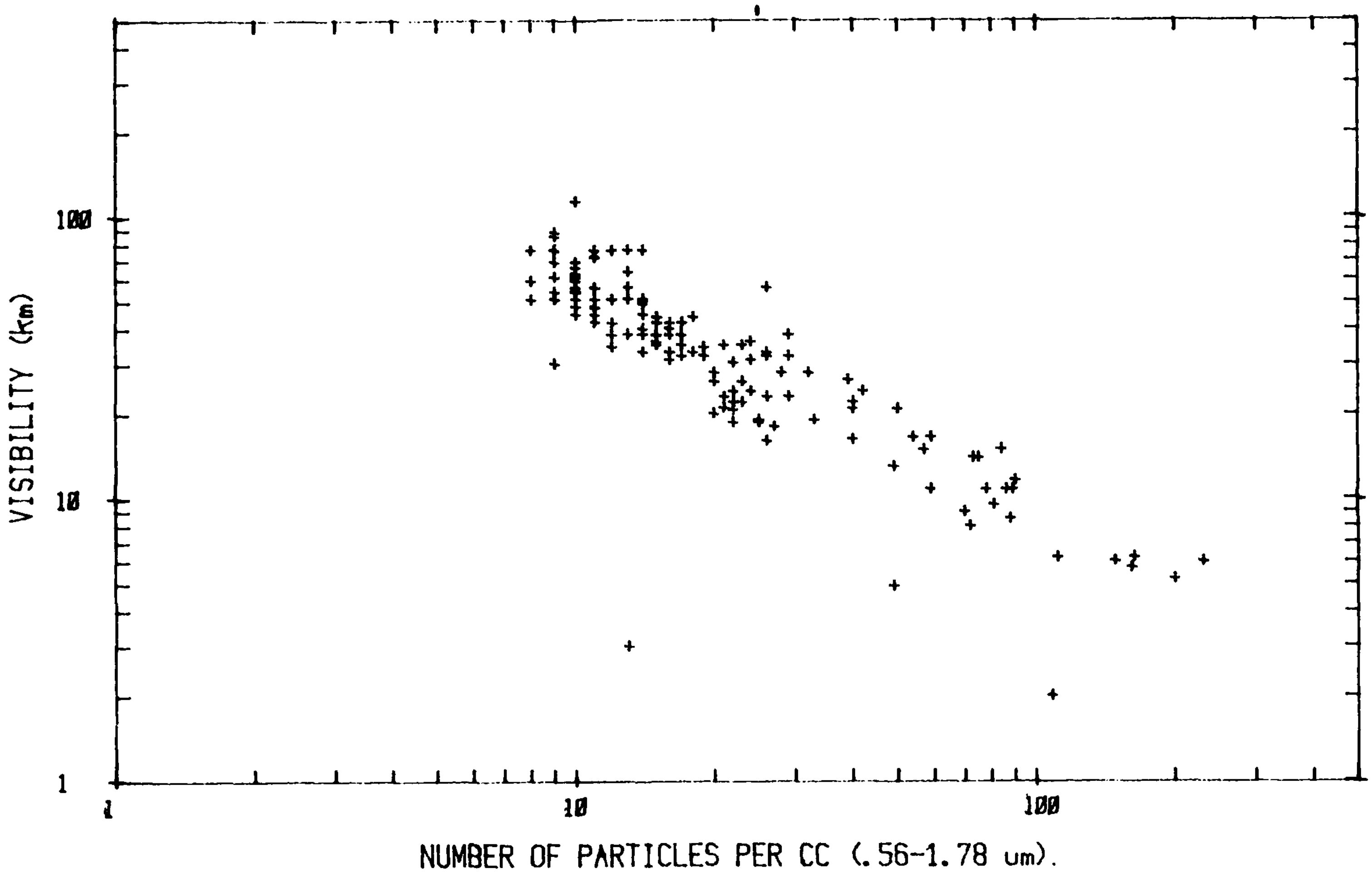


Figure 4. Relationship of Particle Concentration in the 0.56 - 1.78 micron diameter size range to Visibility.

well-developed thermal low over central Spain and weak ridging over Portugal. Thus on the 25th, although the total nuclei concentration was moderate, the sea salt nuclei which could grow most readily into the aerosol size range around 1 um diameter were few, and the aerosol concentration at 1 um appeared to be due to a small concentration of other nuclei present which could grow at this high RH.

The Aitken count on the 26th was near 1500 cm^{-3} which is characteristic of slightly nuclei laden oceanic air (~1000 cm^{-3}), and was the cleanest air experienced during the field program. The surface pressure pattern consisted of a high pressure ridge extending inland over the Iberian penisula similar to that accompanying the two periods of low RH. However, in this case, the air arrived on westerly winds from more subtropical oceanic regions, suggesting both higher RH and lower nuclei content. The wind speed was near 5 m s^{-1} and chemical analyses indicated that sea salt was present. Thus in this case, it appears that sea salt nuclei were present, but in such small numbers along with the other few nuclei present in the relatively clean subtropical-type air, that the aerosol concentration around the 1 um diameter range was low and the visibility was near 40km.

6.4.3 Moderate Visibility and Nuclei Concentration, High RH

A review of the data for three days, 23, 24 and 27 June 1987, reveals that all three days had 1 um diameter particle concentrations between 16 and 26 cm^{-3}, visibilities near 30km and RH of 80%. The Aitken nuclei concentrations for the 23rd and 24th were between 4000 and 5000 cm^{-3}. On the 27th, the count was near 6500 cm^{-3}.

The 23rd and the 24th were similar days with visibilities of 24 and 32 km and 1 um diameter particle concentrations of 22 and 26 cm^{-3}, respectively. Meteorologically over this time period, a transition from high pressure ridging over the Iberian Peninsula to a thermal low over central Spain was taking place.

The majority of observations on the 23rd were taken outside the Straits at $5^{o}W$, the easternmost point of the cruise. The highest wind speeds of the cruise (10m/sec) were encountered here. The nuclei chemistry revealed much sea salt present, consistent with the high wind speed and long overwater fetch associated with the 240^{o} wind direction. Thus, the moderate visibility levels existed primarily due to increased aerosol concentrations associated with increased concentrations of sea salt nuclei.

Although the 1 um diameter particle concentration was higher on the 24th (at 26 cm^{-3}) than on the 23rd (20 cm^{-3}), the slightly higher visibility on the 24th (32km) compared to the 23rd (24km) may be due to slightly lower concentration of aerosols in the next size range below 1 um, 0.316 to 0.562 um. The concentrations in this size range were 20 and 27 cm^{-3} for the 24th and 23rd, respectively. This difference may have resulted from a change in nuclei composition. Particle chemistry data for the 24th shows negligible amounts of NaCl which is consistent with the wind speed (3m/s) and the suggested shorter overwater fetch of the air on the 24th with a 300^{o} wind direction. The chemical composition of the nuclei for the 24th appeared to be mostly non-oceanic type nuclei with perhaps higher deliquescence RH thresholds than those for the oceanic-type

nuclei observed on the 23rd.

The 1 um diameter particle concentration on the 27th was 20 cm^{-3} with a visibility of 28km. The corresponding Aitken nuclei concentration was near 6500 cm^{-3}. Compared to the other two days in this group (the 23rd and 24th), the 27th was similar to the 23rd in terms of visibility, the 1 um diameter particle concentration (20 cm^{-3}) and the 0.3-0.5 um concentration (27 cm^{-3}). The chemistry data suggest less oceanic nuclei and perhaps more continental nuclei with higher deliquescence thresholds, and the higher RH (85%) may have caused these nuclei to activate. The meteorological situation for the 27th was again a transition, from the onshore ridging of the 26th to a well developed thermal low by the 28th. Thus, increased humidity in this transition phase appeared to permit the activiation of more non-oceanic aerosols and produce an aerosol size spectrum and visibility level similar to that on the 23rd when the aerosol was primarily oceanic in nature.

6.4.4 Low Visibility and High Relative Humidity

On the 18th and 19th, the highest 1 um diameter particle concentrations (86 and 54 cm^{-3}, respectively) and the lowest visibilites (11 and 16 km, respectively) occurred. Meteorologically, the 18th was the last day of a long period of quasi-stagnant conditions during which the wind speed was generally light, especially away from the center of the Straits. Although the Aitken nuclei concentration was small (1350 cm^{-3}), the 1 um concentration was high. Temperature profiles from radiosondes showed a relatively shallow boundary layer of 200-400m on the 17th and the 18th. Moisture from the ocean surface was

concentrated in this layer, and the long period of quasi-stagnant flow had apparently allowed many of the relatively few nuclei present to grow into the 1 um diameter size range.

The Aitken nuclei concentration for the 19th increased to 6000 cm^{-3}, reflecting on the influence of the east-southeast flow of air through the Straits. The corresponding continental character of the air was reflected in the aerosol chemistry which showed small amounts of sea salt but large amounts of silicates, aluminum and iron. The boundary layer depth was only 100 meters on the 19th. Thus the moisture evaporating from the ocean surface was confined to a shallow layer, and those hygroscopic nuclei which were present in the continental-type air could grow into the 1 um diameter size range.

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APPENDIX A
USNS LYNCH HOURLY METEOROLOGICAL OBSERVATIONS

The data contained in the tables on the following pages summarize the hourly observations of meteorological conditions during the USNS Lynch cruise. Dry and wet bulb temperatures were obtained with a sling psychrometer. Relative humidity was obtained from psychrometric tables. True wind direction and speed were calculated from observed ships wind direction and speed and ship' heading and speed. Visibility was obtained from the HSS Visibility meter. Calibration of the HSS was performed at the beginning, middle, and end of the cruise. Reported particle concentrations obtained with the Gardner Small Particle Detector are the average of at least three readings taken in rapid succession at the reported time. Aerosol optical depth was obtained from sun photometer readings and reduced using the procedure outlined in Appendix C. The optical depth computation does not work well for large zenith angles; therefore optical depths for times before 0900 and after 1500 should be treated with extreme caution.

Samples obtained for drop replicate and elemental analysis are indicated by an 'X' at the appropriate sample time.

Day/Hour (GMT)	Temperature °F Dry BULB	Temperature °F Wet BULB	RH (%)	Winds Direction (°TRUE)	Winds Speed (meters/sec)	Cloud Cover & Weather
17/0900	-	-	-	320	3.4	-
1100	67	63	80	313	2.8	St ovc, sun dimly vsbl.
1200	68	63	76	306	1.8	0.3 Ci, St to north. Sun hazy.
1300	70	64	72	-	-	0.2 Ci, thin Ci near sun.
1400	73	66	69	329	2.1	0.1 Ci NE horizon. Clr overhead.
1425	-	-	-	310	2.1	-
1500	70.5	65	79	290	3.6	0.1 Ci NE-E horizon. Clr overhead.
1600	71	65	72	272	3.1	0.2 Ci Wand NW sectiors. Sun clear.
1700	69	64.5	79	-	-	0.3 Ci spreading in from west. Sun clear.
1800	69	64.5	79	-	-	0.7 Cu west half of sky. Sun hazy.
17/1900	67	63.2	81	-	-	0.4 Ci scattered thruout sky.

Day/Hour (GMT)	Visibility (km)	Particle Concentration (number/cm^3)	Aerosol Optical Depth (502nm)	Drop Replicate (>3 um)	Casella Impactor (for chemistry)
17/1100	14	1550	-		
1200	14	1550	0.25		
1300	17	1350	0.15		
1400	19	-	0.12		
1500	16	2400	0.14		
1600	16	4200	0.21		
1700	15	1200	0.19		
1800	14	1200	-		
17/1900	12	1800	-		

Day/Hour (GMT)	Temperature °F Dry BULB	Wet BULB	RH (%)	Winds Direction (°TRUE)	Speed (meters/sec)	Cloud Cover & Weather
18/0600	67	64	85	330	2.1	0.9 Ci and CiCu. Hazy, sun vsbl thru Ci.
0700	69	67	90	110	6.7	Squall. Numerous whitecaps. 0.9 Ci, haze. Sun dimly vsbl.
0800	-	-	-	89	7.8	-
0815	69.5	67.5	90	-	-	0.7 Ci, hazy. St bank to south.
0900	68	66	90	200	2.6	0.9 Ci, St bank to E. Whitecaps have stopped.
1030	68	65	85	226	1.2	St ovc, hazy. Few bright spots, sun not visible.
1100	72.5	67	75	246	1.0	St ovc, few breaks. Sun's disk vsbl.
1200	70.5	66	79	270	1.5	0.3 Ci, 0.4 St, hazy sun thru breaks.
1300	70	67.5	88	80	3.1	Dim sun, 0.7 St in patches, Ci above.
1400	71	67	81	315	3.1	Ci ovc and St, sun disk vsbl.
1600	68.5	66	88	88	6.4	0.9 Ci, haze.
1800	69	66	85	129	6.5	0.9 Ci and CiCu. Haze and fog bank to NW.
18/1900	69	65.5	83	133	5.2	0.9 Ci and CiCu. Brown smoke layer hugging Spanish coast.

Day/Hour (GMT)	Visibility (km)	Particle Concentration (number/cm^3)	Aerosol Optical Depth (502nm)	Drop Replicate (>3 um)	Casella Impactor (for chemistry)
18/0600	9.5	3800	-		
0700	5.3	2350	-		
0815	4.3	3800	0.38		
0900	6.2	-	0.59		
1030	10.8	2350	-		
1100	11.6	1350	-		
1130	-	-	-		X
1200	10.8	1350	-		
1300	9.0	5900	-		
1400	9.5	-	-		
1600	8.0	6600	-		
1800	10.8	9000	-		
18/1900	13	2650	-		

Day/Hour (GMT)	Temperature °F Dry BULB	Wet BULB	RH (%)	Winds Direction (°TRUE)	Speed (meters/sec)	Cloud Cover & Weather
19/0600	67	65.5	92	213	2.5	High thin Ci, very hazy. Seas calm.
0700	68	65.5	88	036	1.4	Same conditions.
0800	69	67	90	-	-	No change.
0900	70	67	86	-	-	Hazy sun, Ci to East.
0920	-	-	-	163	3.5	-
1000	70.7	67.8	86	-	-	Ci distant E (0.1), clr overhead and at sun.
1020	-	-	-	133	5.7	-
1100	72	67	77	129	8.8	0.2 CiSt To E. Sun clear. Breezy.
1215	71	66.5	79	127	8.2	0.3 Ci to E only. Hazy, Clear sun.
1300	72.3	67.3	77	120	7.7	0.3 Ci to E.
1400	72	66.7	76	122	7.7	0.3 Ci to E. Clr with anvil to North.
1500	74.5	65.0	60	255	2.6	0.2 Ci to E.
1600	70.8	67.8	86	-	-	0.1 Ci to E. Sun clear.
1700	70.2	68	89	286	4.1	Very hazy.
19/1800	69.8	67.8	90	285	3.1	Very hazy. Low stratus forming.

Day/Hour (GMT)	Visibility (km)	Particle Concentration (number/cm^3)	Aerosol Optical Depth (502nm)	Drop Replicate (>3 um)	Casella Impactor (for chemistry)
19/0600	2.0	2000	-		
0700	6.2	2400	0.51		
0800	5.7	7400	0.42	X	X
0900	10.8	18000	0.22		
1000	16.5	5900	0.19	X	X
1100	20.8	7300	0.18		
1215	16.5	5900	0.22	X	X
1300	14.9	4700	0.20		
1400	26.4	2000	0.23		
1500	20.8	-	0.23		
1600	8.5	4700	0.33		
1700	6.0	3000	0.45		
19/1800	4.7	-	-		

Day/Hour (GMT)	Temperature °F Dry BULB	Wet BULB	RH (%)	Winds Direction (°TRUE)	Speed (meters/sec)	Cloud Cover & Weather
20/0600	68	65.5	87	-	-	St ovc, few breaks
0700	68	66	90	267	4.1	St and StCu ovc, few breaks. Hazy
0800	68	65.5	88	277	4.3	St ovc.
0900	67.5	64	83	257	8.2	St ovc.
1000	69	66.8	89	298	5.1	0.8 St Cu, clr to NW.
1100	68	63.5	78	301	5.1	0.8 St Cu, Clr to NW.
1230	69	63.5	74.2	305	5.8	0.8 St Cu to E. Few Cu to North.
1320	68	62	71	303	6.7	0.8 St to E, thin Ci overhead.
1410	68	63	76	297	5.2	0.9 St, Cu, Alto Cu, Ci.
1500	67.2	62.3	76	300	5.7	0.7, same cloud types.
1600	68.5	61.5	67	282	6.5	0.2 Ci, clr overhead, small whitecaps.
1700	67.5	62.5	75	-	-	0.2 Ci, clr overhead.
1730	-	-	-	280	7.7	-
20/1800	67	60.8	70	264	5.4	0.1 Ci, hazy.

Day/Hour (GMT)	Visibility (km)	Particle Concentration (number/cm^3)	Aerosol Optical Depth (502nm)	Drop Replicate (>3 um)	Casella Impactor (for chemistry)
20/0600	6.0	2000	-		
0700	5.2	44000	-		
0800	4.9	-	-	X	X
0900	24	12000	-		
1000	24	5300	-	X	X
1100	34.4	4700	-		
1200	50	3350	0.45	X	X
1230	61	-	0.33		
1320	44	9000	-		
1410	44	10000	-		
1500	44	5800	-		
1600	61	6000	0.15		
1700	23	25000	0.21		
20/1800	56	7800	0.24		

Day/Hour (GMT)	Temperature °F Dry BULB	Wet BULB	RH (%)	Winds Direction (°TRUE)	Speed (meters/sec)	Cloud Cover & Weather
21/0500	65	60	75	307	4.6	0.8 St Cu, denser to E, clearing to W. Few whitecaps.
0600	65	60	75	-	-	0.8 St Cu bank to E-SE, Cu and clear to NW.
0700	65.5	60	72	325	6.2	Same as 0600.
0800	65	59	70	299	5.7	Still 0.8 St Cu.
0900	65	58.5	68	320	6.7	0.7 St Cu and Cu, to W 0.3 Cu in streets.
0933	65	59.8	73	308	6.2	0.5 Cu and St Cu. Sun clear.
1030	65	59	70	291	7.7	0.3 Cu to south, sun very bright. No Ci.
1100	66	59.5	68	278	4.1	0.2 Cu to South.
1200	66.2	59.8	67	295	5.7	0.2 Cu distand S&E horizons. Sun bright.
1230	65.5	59.5	71	-	-	No change from 1200. Balloon launch.
1300	65	59.5	72	264	4.6	0.1 Cu distant E. Few wisps of Cu overhead, no near sun.
1400	66.5	60	68	281	5.1	0.1 Cu, mainly to west now.
1500	68	58.5	56	279	5.7	0.2 sct Cu west, sun clear.
1600	66.5	57.8	60	271	3.1	0.1 Cu to west, Cu are thin.
1700	67.2	59.8	64	270	5.1	0.3 Cu mostly over Morocco. Some Cu overhead.
1800	65.5	57.5	61	253	5.1	Haze layer near Tangiers. 0.1 Cu over Morocco.
21/1900	66	57	57	-	-	Same as 1800.

Day/Hour (GMT)	Visibility (km)	Particle Concentration (number/cm^3)	Aerosol Optical Depth (502nm)	Drop Replicate (>3 um)	Casella Impactor (for chemistry)
21/0500	49	7400	-		
0600	56	7400	-		
0700	56	4500	-		
0800	72	13000	-	X	X
0900	72	6500	-		
0933	56	27500	0.06		
1030	56	9000	0.02	X	X
1100	56	25000	0.02		
1200	61	19500	0.03	X	X
1230	50	-	0.00(2)		
1300	66	3700	0.00(3)		
1400	113	-	0.01		
1500	88	11000	0.00(1)		
1600	76	1750	0.05		
1700	63	1350	0.06		
1800	69	2400	0.05		
21/1900	76	-	0.05		

Day/Hour (GMT)	Temperature °F Dry BULB	Temperature °F Wet BULB	RH (%)	Winds Direction (°TRUE)	Winds Speed (meters/sec)	Cloud Cover & Weather
22/0500	65	58	66	-	-	0.5 Cu mostly S-E, some streeting.
0520	-	-	-	317	5.1	-
0600	65	56	56	290	4.6	0.2 Cu and ST Cu to S&E.
0700	66	57	57	-	-	0.1 Cu to E, low on horizon.
0800	65	57.2	62	289	5.1	0.2 Cu to S, sun very clear.
0900	65.5	58.5	66	276	5.7	No change.
1015	-	-	-	-	-	0.1 Cu low on SW horizon.
1040	65.5	58.5	66	250	5.7	No change.
1100	65.5	58.5	66	246	6.7	No change.
1200	67	59.5	64	247	7.2	0.1 Cu far W horizon, sun clear.
1300	67	60.5	69	249	7.7	0.1 Cu far west.
1400	67	60	66	264	6.2	0.1 Cu; some whitecaps forming.
1500	67	60	66	274	9.3	0.1 Cu to W; whitecap area upwind.
1600	67	60	66	266	6.7	No clouds, small whitecaps.
1700	68	61.5	69	293	6.2	Unchanged.
1800	66.5	60.5	71	-	-	Unchanged.
22/1820	-	-	-	270	5.7	-

Day/Hour (GMT)	Visibility (km)	Particle Concentration (number/cm^3)	Aerosol Optical Depth (502nm)	Drop Replicate (>3 um)	Casella Impactor (for chemistry)
22/0500	40	19500	0.21		
0600	69	6700	0.06		
0700	76	-	0.03		
0800	76	33000	0.03	X	X
0900	76	13500	0.01		
1015	51	-		X	X
1040	51	7300	0.01		
1100	51	9000	0.01		
1200	51	9000	0.02	X	X
1300	51	10000	0.02		
1400	42	34000	0.01		
1500	42	24000	0.01		
1600	51	6600	0.01		
1700	51	2400	0.03		
22/1800	45	3000	0.06		

Day/Hour (GMT)	Temperature °F Dry BULB	Wet BULB	RH (%)	Winds Direction (°TRUE)	Speed (meters/sec)	Cloud Cover & Weather
23/0600	64	60.5	82	296	6.8	0.2 St Cu, overland only.
0700	64	60.3	80	337	5.5	Skies clear, at Rock of Gibraltar.
0800	65	60	75	289	5.1	0.3 St Cu overland to W. In Gibraltar harbor.
0850	67	60.2	67	283	7.6	0.2 St Cu overland to W. Hazy
1015	66.2	63	84	236	9.8	Few Cu to W, skies mostly clear. White caps common.
1100	67	63	80	237	11.3	Same as last observation.
1200	66	62.5	82	244	10.8	0.1 Cu distant W, whitecaps.
1300	68	63.8	80	241	13.9	Same as last observation.
1400	68	64	83	240	15.4	No change in conditions.
1500	67.1	64.5	86	227	9.0	0.1 Cu, encountering haze from fires on land.
1600	66.5	64.0	87	235	7.0	Clear skies, hazy. Smoke from fires behind us.
1700	66.5	64	87	252	5.7	Clear skies, hazy.
23/1800	67	64.2	86	-	-	Clear, hazy.

Day/Hour (GMT)	Visibility (km)	Particle Concentration (number/cm^3)	Aerosol Optical Depth (502nm)	Drop Replicate (>3 um)	Casella Impactor (for chemistry)
23/0530	35	12,000			
0600	35	10,000	0.04		
0700	30.4	44,000	0.03		
0800	42	19,500	0.05		
0830	-	--	--	x	x
0900	28	15,500	0.04		
1015	18.6	4,400	0.03		
1030	-	--	--	x	x
1100	26.3	4,800	0.02		
1200	23.8	27,000	0.03	x	x
1300	33	11,000	0.02		
1400	32	14,000	0.10		
1500	23	12,000	0.05		
1600	19.5	7,300	0.05		
1700	38	18,000	0.06		
23/1800	32	23,000	0.06		

Day/Hour (GMT)	Temperature °F Dry BULB	Wet BULB	RH (%)	Winds Direction (°TRUE)	Speed (meters/sec)	Cloud Cover & Weather
24/0630	65	62	85	244	3.6	0.7 Ci in streaks
0700	66	62.5	82	261	5.7	0.7 Ci
0800	66.5	63	85	249	5.0	0.7 Ci, hazy sun
0900	66.5	63.8	85	267	7.1	0.7 Ci covering sun
1000	68.2	63.8	78	287	4.2	0.6 Ci
1100	68.5	64.5	80	329	3.7	0.6 Ci (fibratus) intervening sun
1200	69.5	65.0	79	297	4.6	0.6 Ci, not at sun now
1300	71.5	65.2	70	296	5.1	0.3 Ci, clr near sun
1545	70.8	65.0	72	219	6.8	Clear
1700	69.0	64.5	72	282	5.1	Clear
24/1800	68.0	64.0	80	274	6.1	Clear

Day/Hour (GMT)	Visibility (km)	Particle Concentration (number/cm^3)	Aerosol Optical Depth (502nm)	Drop Replicate (>3 um)	Casella Impactor (for chemistry)
24/0700	28	3300	0.09		
0800	23	3700	0.13	x	x
0900	22	7000	0.16		
1000	38	3700	0.10		
1030	--	--	--	x	x
1100	32	7000	0.20		
1200	33	3300	0.08	x	x
1300	32	4300	0.11		
1545	35	5900	0.09		
1700	36.2	3300	0.14		
24/1800	35	3300	0.22		

Day/Hour (GMT)	Temperature °F Dry BULB	Wet BULB	RH (%)	Winds Direction (°TRUE)	Speed (meters/sec)	Cloud Cover & Weather
25/0600	66.4	64.8	92	245	3.0	0.7 St Cu, no whitecaps.
0700	66	64	90	227	2.8	0.6 St Cu, few whitecaps.
0800	67.2	65.2	90	280	3.5	0.4 St Cu, no whitecaps.
0900	68.2	65.8	88	302	3.9	0.3 St Cu, clr overhead, hazy
1000	68.2	66	90	309	3.1	0.2 St Cu, near coast.
1100	68	66	90	309	3.1	0.2 St Cu near coast, hazy.
1200	69	65.2	81	293	3.5	0.1 Cu over mtns, hazy aloft.
1300	69.5	66	83	328	2.1	Few Cu over mtns, mostly clr hazy.
1400	70	66	81	285	4.1	Clear, some haze.
1500	68	65.8	90	288	3.3	Clear, hazy, no whitecaps.
1600	69.0	65.0	81	277	3.6	Clear, hazy.
1700	69	66	85	295	2.2	Clear, hazy, calm seas
25/1800	68	65.2	86	272	4.1	Clear, hazy, calm seas

Day/Hour (GMT)	Visibility (km)	Particle Concentration (number/cm^3)	Aerosol Optical Depth (502nm)	Drop Replicate (3 um)	Casella Impactor (for chemistry)
25/0600	18.6	9000	--		
0700	16.2	3300	--		
0800	20.6	1500	0.25		
0900	33.1	900	0.22		
1000	38.1	7000	0.16		
1100	47.6	5900	0.20		
1200	54.4	3300	0.18	x	x
1300	38.1	3000	0.18		
1400	50.8	2100	0.19		
1500	42.3	3700	0.16		
1600	33.1	2500	0.15		
1700	44.8	1800	0.21		
25/1800	34.6	2050	0.20		

Day/Hour (GMT)	Temperature °F Dry BULB	Wet BULB	RH (%)	Winds Direction (°TRUE)	Speed (meters/sec)	Cloud Cover & Weather
26/0550	66.5	64.5	90	331	2.1	0.9 St Cu, calm seas
0713	66.5	64.2	87	calm	0	Same
0800	69.0	64.5	76	286	3.3	0.4 St Cu, clr overhead
0900	70.8	67.5	86	299	3.1	0.2 St Cu
1000	70.0	65.0	77	279	2.6	0.1 St Cu
1100	70.0	65.0	77	280	4.1	Clear
1200	69.8	65.8	81	284	4.6	Clear, few whitecaps, light haze
1300	69.0	66.0	85	282	5.1	Same
1400	69.5	65.2	80	285	6.2	Same
1500	69.8	65.8	81	291	5.7	Same
1600	69.5	66.0	79	292	5.1	Same, few Cu over mtns.
26/1700	70.0	66.5	79	279	5.1	Same

Day/Hour (GMT)	Visibility (km)	Particle Concentration (number/cm^3)	Aerosol Optical Depth (502nm)	Drop Replicate (3 um)	Casella Impactor (for chemistry)
26/0550	33.1	4300	--		
0700	40.1	8000	--		
0800	54.4	1350	0.20	x	x
0900	54.4	1350	0.22		
1000	50.8	1200	0.13	x	x
1100	50.8	1500	0.07		
1200	44.8	2000	0.05	x	x
1300	44.8	1800	0.08		
1400	76.1	2350	0.06		
1500	84.6	750	0.06		
1600	76.1	900	0.06		
26/1700	50.8	750	0.06		

Day/Hour (GMT)	Temperature °F Dry BULB	Temperature °F Wet BULB	RH (%)	Winds Direction (°TRUE)	Winds Speed (meters/sec)	Cloud Cover & Weather
27/0600	66.5	64.8	92	020	1.0	St deck to E; calm seas.
0700	65.8	64.8	95	313	3.4	St to E and S
0800	69.8	66.8	86	252	2.1	0.8 Bkn stratus in all quadrants
0900	70.0	67.0	86	272	1.5	0.1 St mainly over land. Sun appears clear.
1000	69.5	66.2	86	280	2.6	Same
1100	70.5	66.5	81	264	4.1	0.1 StCu over land, light haze, calm seas
1200	70.0	66.6	86	275	4.1	Clear, light haze, few whitecaps
1300	70.0	67.4	88	265	4.6	Same
1400	73.0	68.2	75	276	6.2	Same
1500	72.0	67.0	77	285	6.2	Same
1600	72.2	67.8	81	292	4.6	Clear with haze, more whitecaps
1700	71.8	67.0	77	289	5.7	Clear with haze, fewer whitecaps
28/1800	71.0	67.2	82	305	5.1	Same

Day/Hour (GMT)	Visibility (km)	Particle Concentration (number/cm^3)	Aerosol Optical Depth (502nm)	Drop Replicate (3 um)	Casella Impactor (for chemistry)
27/0600	2 6	6800	-		
0700	38.1	6800	0.08		
0800	38.1	9000	0.09	X	X
0900	40.1	4300	0.09		
1000	38.1	6800	0.06	X	X
1100	30.5	7200	0.07		
1200	28.2	4300	0.10	X	X
1300	30.5	8200	0.08		
1400	33.1	8200	0.10		
1500	42.3	3500	0.10		
1600	38.1	3800	0.09		
1700	42.3	3800	0.14		
27/1800	42.3	4700	0.13		

Day/Hour (GMT)	Temperature °F Dry BULB	Temperature °F Wet BULB	RH (%)	Winds Direction (°TRUE)	Winds Speed (meters/sec)	Cloud Cover & Weather
28/0600	65.5	63.5	90	232	5.1	Lazy at surface; Cu over mtns.
0700	66.5	64.5	90	195	3.6	0.4 St to N, Al to St and Ci to NE. Misty along coasts.
0800	68.5	65.2	85	237	4.1	0.4 St
0900	68.8	66.5	90	236	3.6	0.3 StCu to N half, few whitecaps
1000	70.4	67.5	86	244	5.1	0.2 St, Lazy, Whitecaps.
1100	71.8	68.5	84	254	6.4	Same
1200	71.2	66.8	77	262	6.2	0.1 Cu over Moroccan coastal mountains.
1300	71.3	66.8	77	276	5.9	Clear, hazy. Few small whitecaps.
1400	70.5	66.7	82	281	5.9	Same. Land features appear clearer & sharper.
1500	70.5	65.9	79	274	5.5	Same
1600	70.0	66.0	81	280	4.9	Same, yellow-green haze over Tangiers along coast to NE.
1700	70.5	64.2	71	269	3.0	Clear, haze not as prominent, ship's exhaust observed hitting inversion base.
28/1800	70.5	64.2	71	275	5.1	Clear, hazy.

Day/Hour (GMT)	Visibility (km)	Particle Concentration (number/cm^3)	Aerosol Optical Depth (502nm)	Drop Replicate (3 um)	Casella Impactor (for chemistry)
28/0600	21.8	1000	0.14		
0700	21.8	4250	0.14		
0800	21.1	3400	0.14	X	X
0900	17.7	5200	0.11		
1000	19.0	1800	0.10	X	X
1100	26.3	2350	0.07		
1200	38.1	4200	0.08	X	X
1300	36.3	3000	0.05		
1400	47.6	3000	0.04		
1500	50.8	3750	0.05		
1600	47.6	2650	0.10	X	X
1700	76.1	3000	0.06		
28/1800	58.6	3400	0.07		

Day/Hour (GMT)	Temperature °F Dry BULB	Wet BULB	RH (%)	Winds Direction (°TRUE)	Speed (meters/sec)	Cloud Cover & Weather
29/0600	65.5	63.9	92	228	4.1	0.2 St over Moroccan coast. Sun clr. Misty over water sfc.
0700	67.0	64.8	89	225	6.7	St Cu over both coasts. Few Cu to west.
0800	69.0	65.0	81	237	5.1	0.4 Cu over coasts, clear sun, few whitecaps.
0905	70.2	63.5	69	273	4.9	0.4 Bkn Cu mainly to E. Large increase in visibility.
0930	68.0	62.3	73	268	3.1	Cu are gone. Sun clear. Frontal passage?
1019	68.8	62.5	71	281	5.1	Clear.Few Cu over mtns.
1110	68.5	63.0	74	272	5.4	Clear. No clouds in entire sky.
1205	68.5	62.0	69	282	5.7	Same. Highest sun photometer reading this cruise.
1340	70.0	61.9	64	288	5.1	Same sky. Few whitecaps.
1410	71.0	63.0	64	262	4.2	Clear. Under way to Rota.
1510	70.0	63.2	68	290	5.1	Clear.
29/1605	70.0	63.0	68	282	6.1	Clear. Few whitecaps. Begin equipment pack-up.

Day/Hour (GMT)	Visibility (km)	Particle Concentration (number/cm^3)	Aerosol Optical Depth (502nm)	Drop Replicate (3 um)	Casella Impactor (for chemistry)
29/0600	15.2	-	0.07		
0700	19.0	-	-		
0800	19.0	3000	0.07	X	X
0900	38.1	5150	0.06		
0930	42.3	4600	0.05		
1000	42.3	4800	0.02	X	X
1100	42.3	3750	0.00(3)		
1200	50.8	2700	0.02	X	X
1330	58.6	1800	0.02		
1400	76.1	1800	0.01		
1500	76.1	5200	0.00(3)		
29/1600	63.5	3000	0.01	X	X

APPENDIX B
AEROSOL SIZE SPECTRA AND ELEMENTAL PARTICLE COMPOSITION FOR THE USNS LYNCH CRUISE

Aerosol size distributions and individual particle elemental composition are presented in this appendix.

Particle size distributions are shown in both plotted and tabular form. Plotted size distributions are presented only for those times when data was available from all three particle size analyzers (EAA, Royco, and Drop Replicates) and cover particle diameters from 0.01 microns to 100 microns. Because each instrument has it's own characteristic particle size channel widths, the number concentration of particles in each channel shown in the plotted data only was normalized to a one micron wide channel width. The size analysis procedure for the drop replicate is presented in detail in reference (1) below.

In tabular format, the size distribution data is presented in number of particles per cubic centimeter of air within the indicated size ranges (diameters).

Elemental particle composition is presented as the percentage of particles containing a given element. The analysis procedure is detailed elsewhere.[2]

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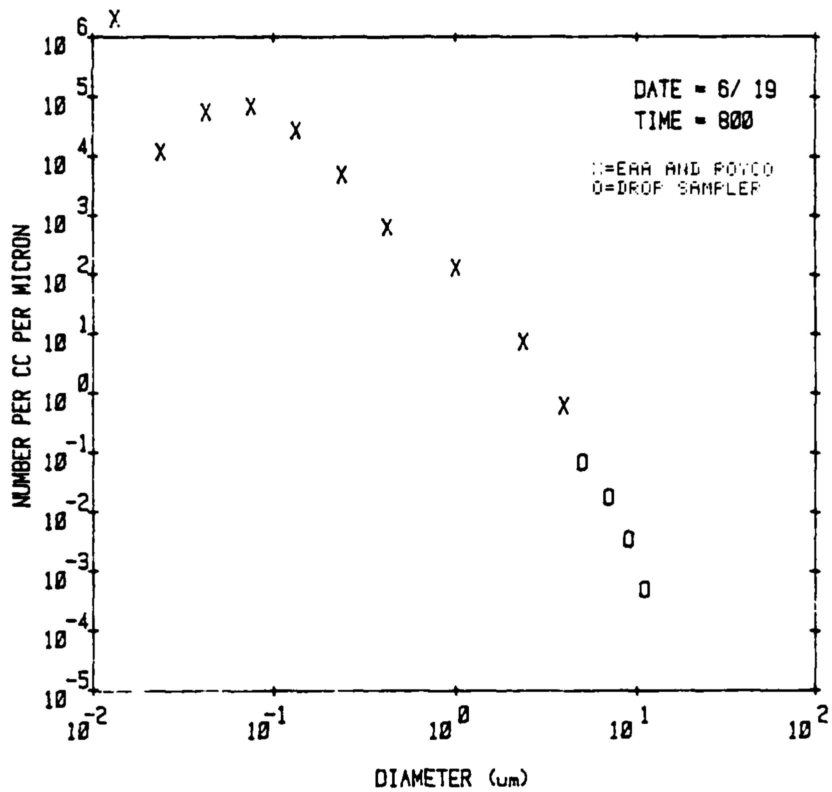
(1) Mack, E.J., B.J. Wattle, C.W. Rogers, and R.J. Pilie, 1980 "Fog Characteristics at Otis AFB, MA", Calspan Report No. 6655-M-1, 77 pp.

(2) Mack, E.J., R.J. Anderson, C.K. Akers, and T.A. Niziol, 1978 "Aerosol Characteristics of the Marine Boundary Layer of the North Atlantic and Mediterranean During May-June 1977", Calspan Report 6232-M-1, 215 pp.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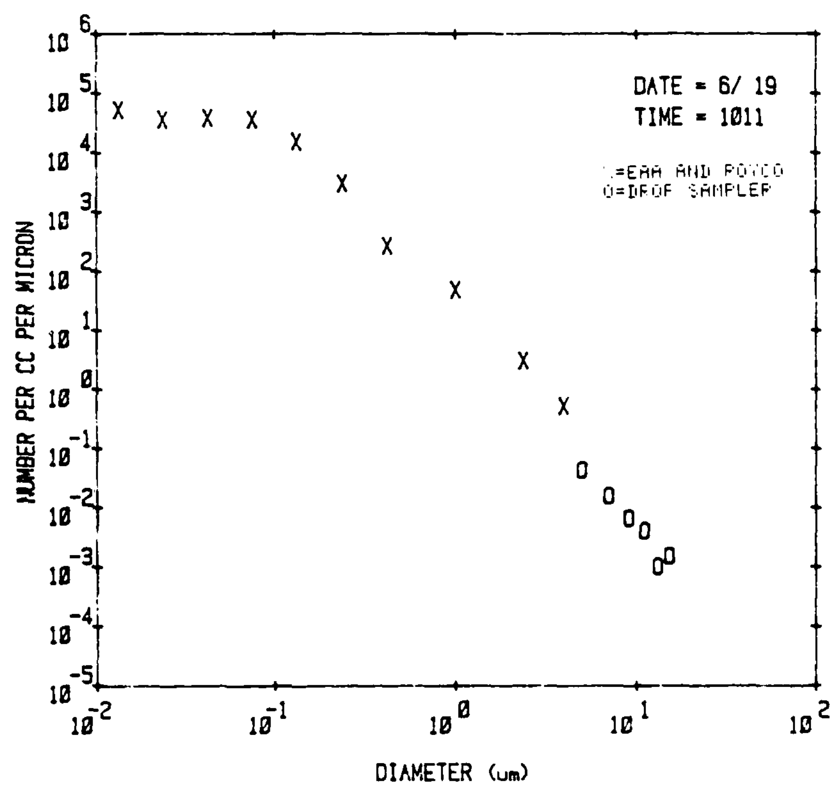
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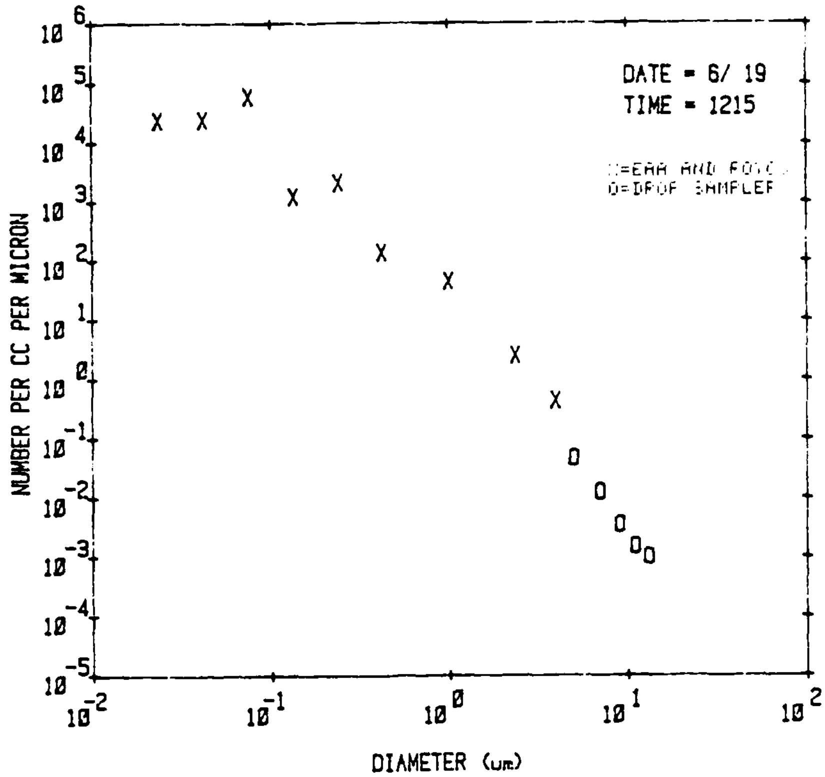
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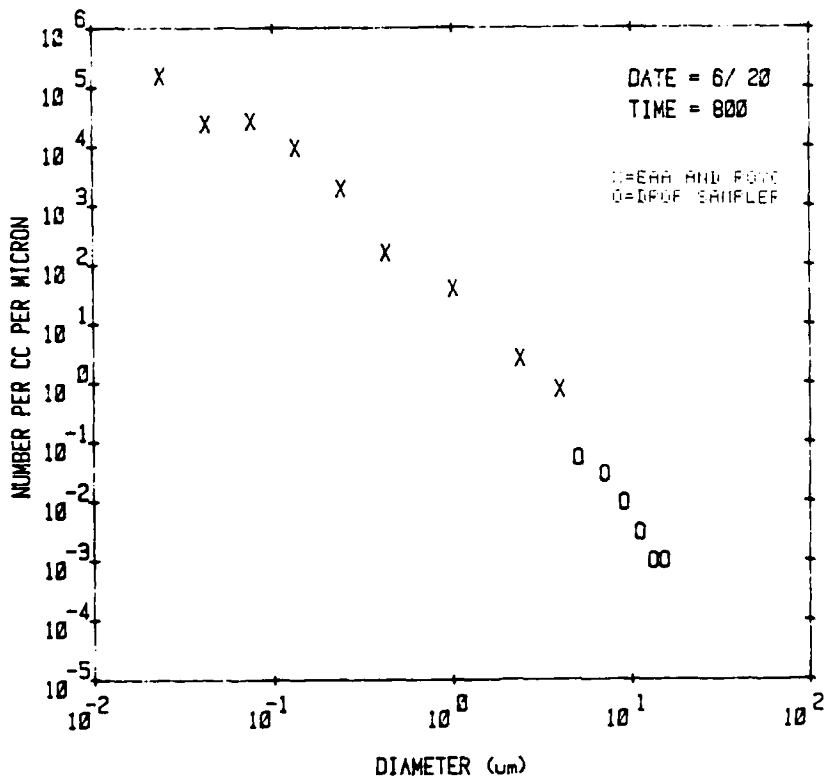
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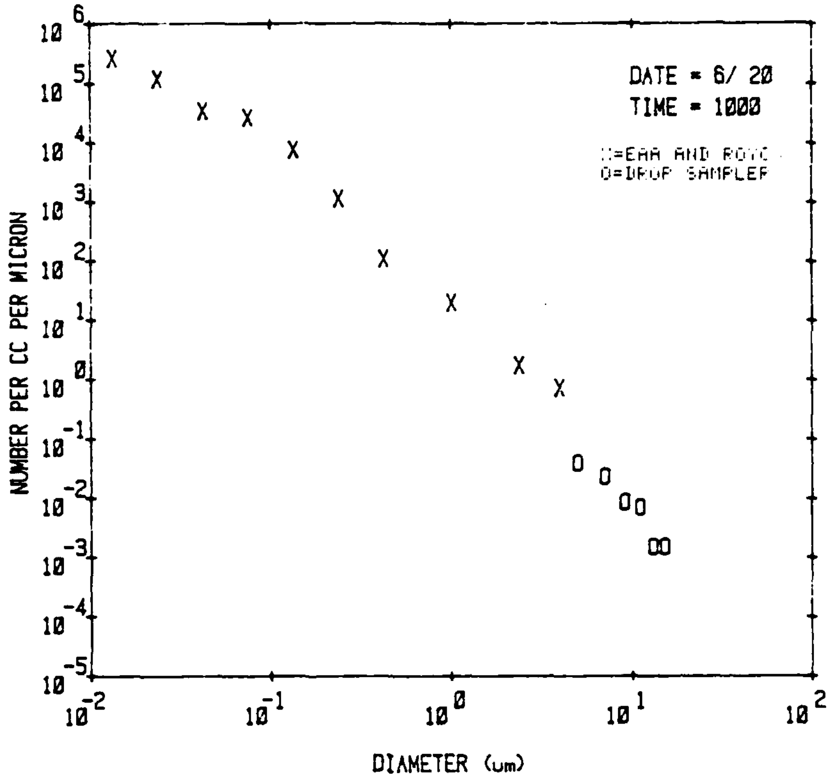
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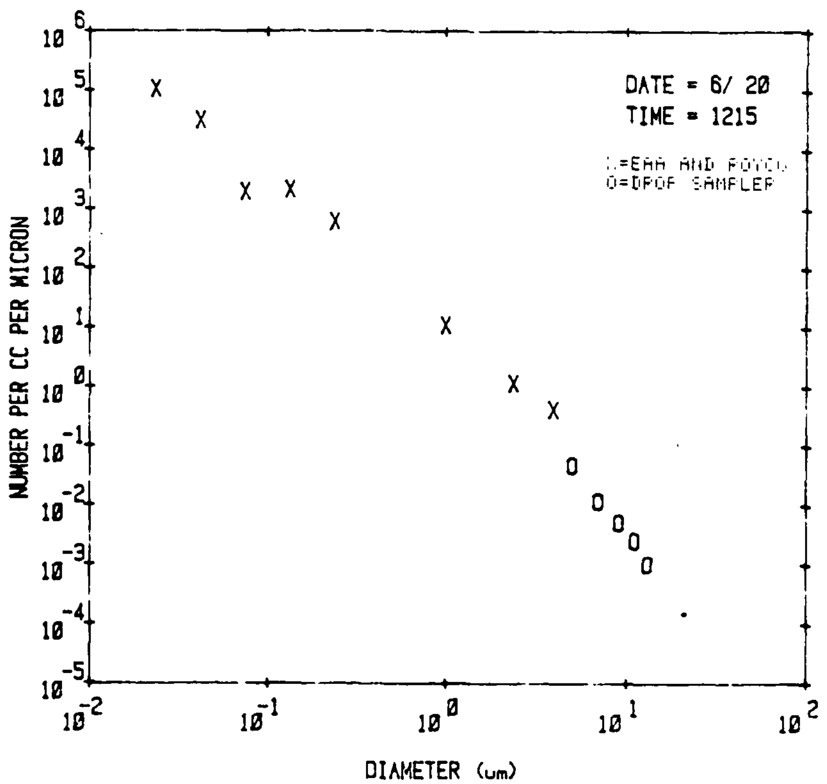
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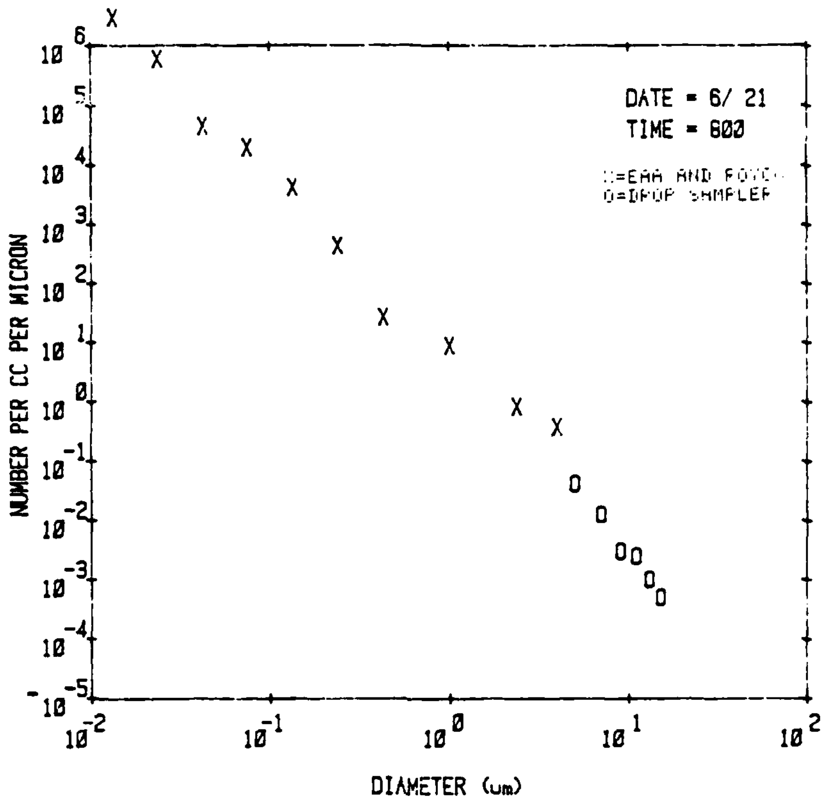

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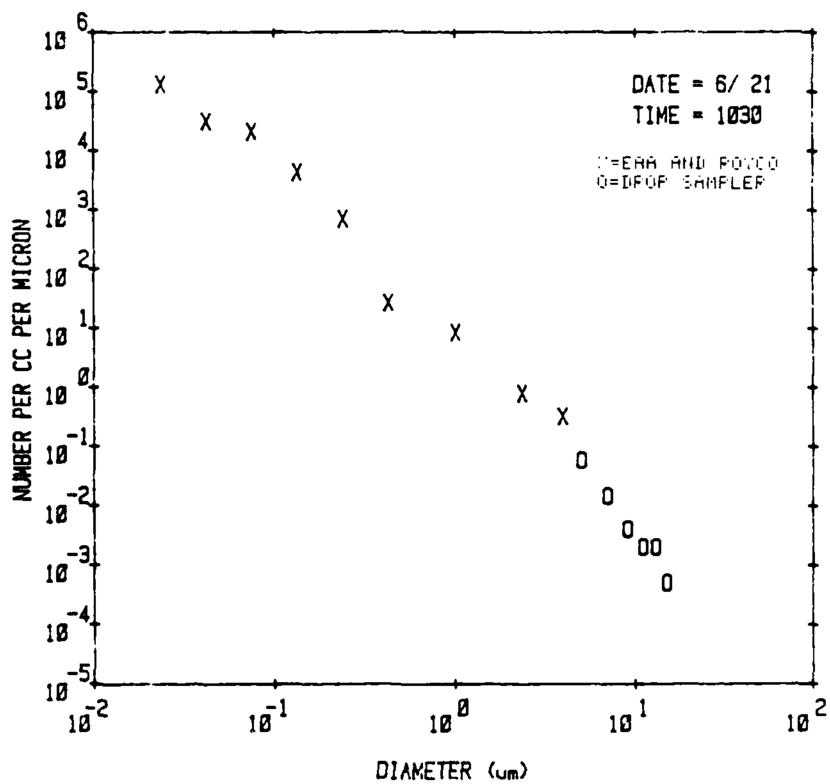

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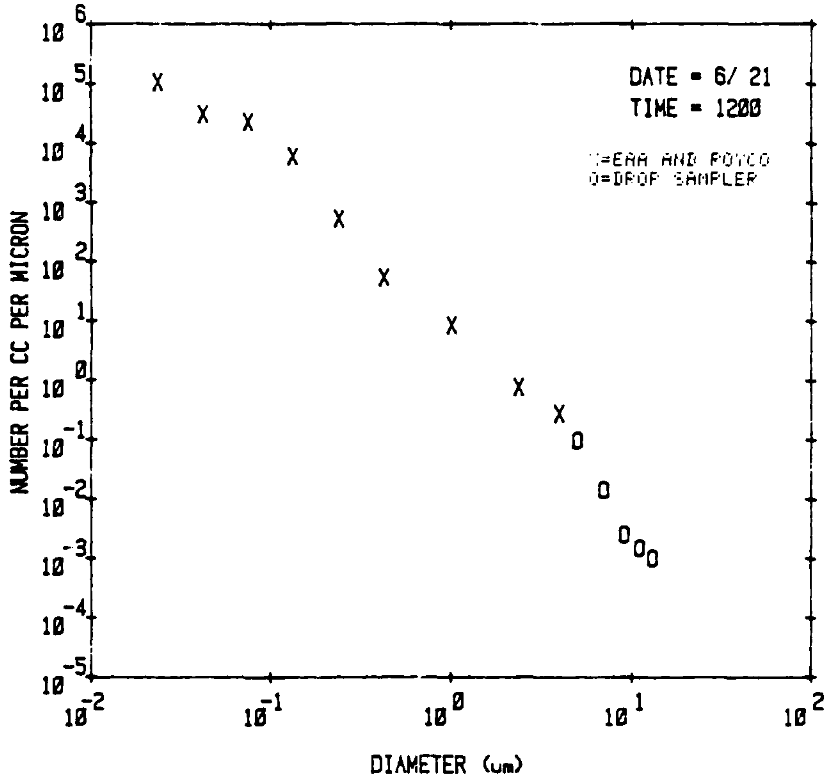

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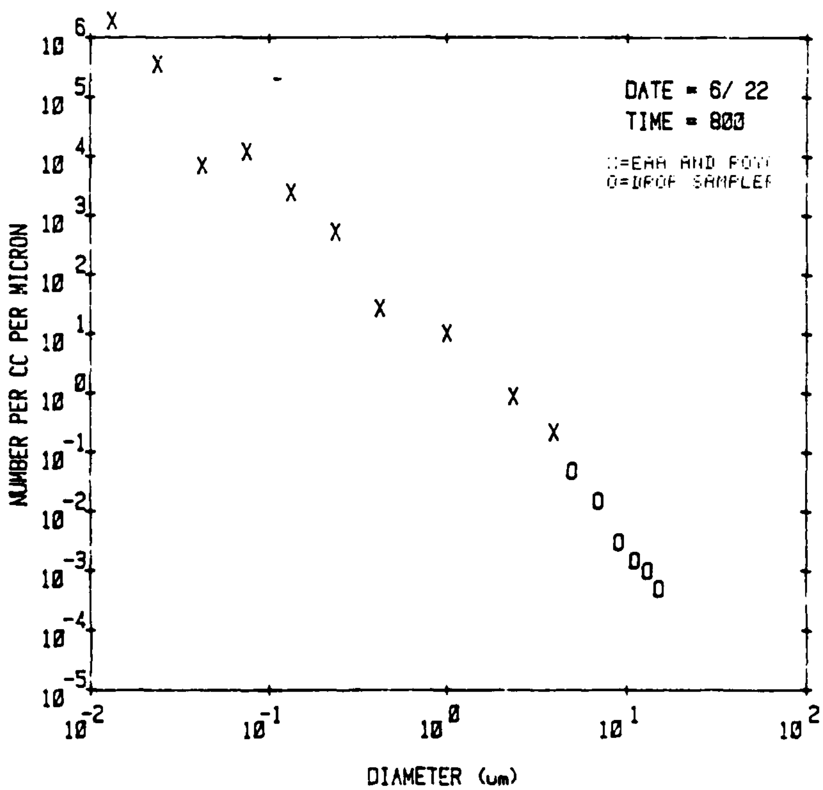

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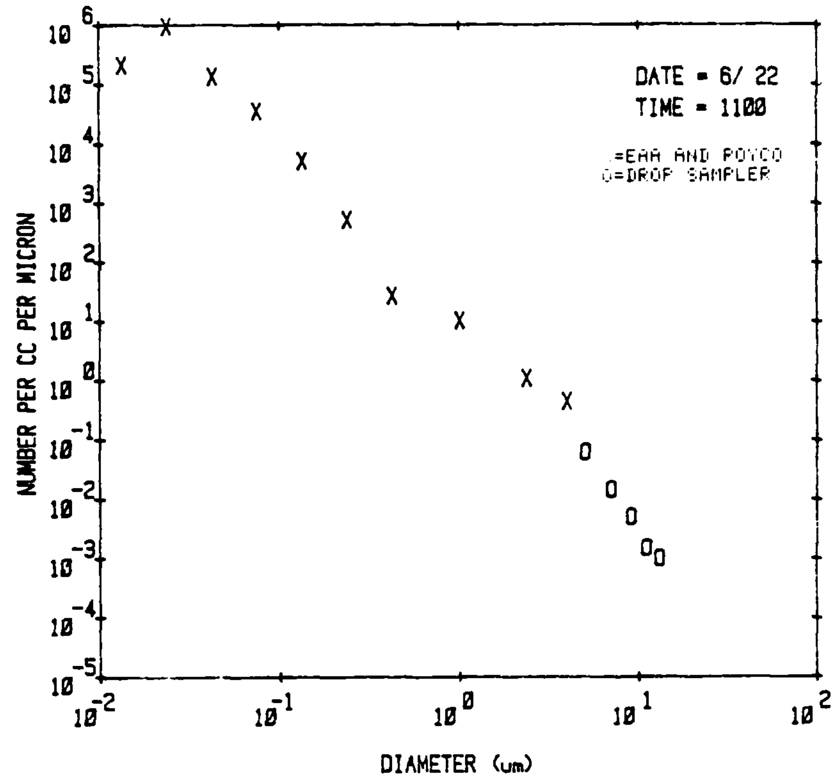
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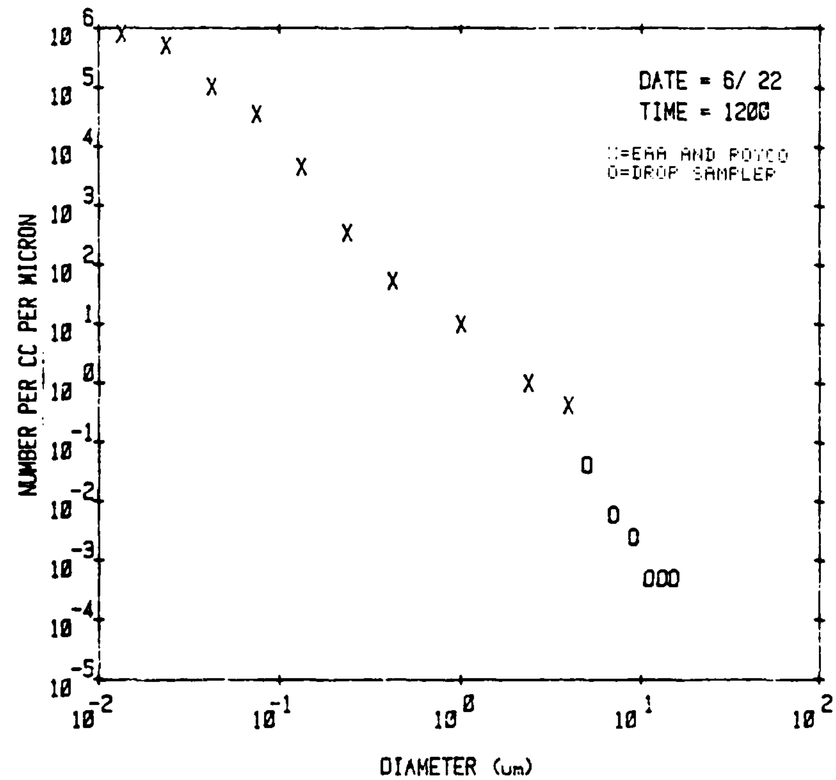
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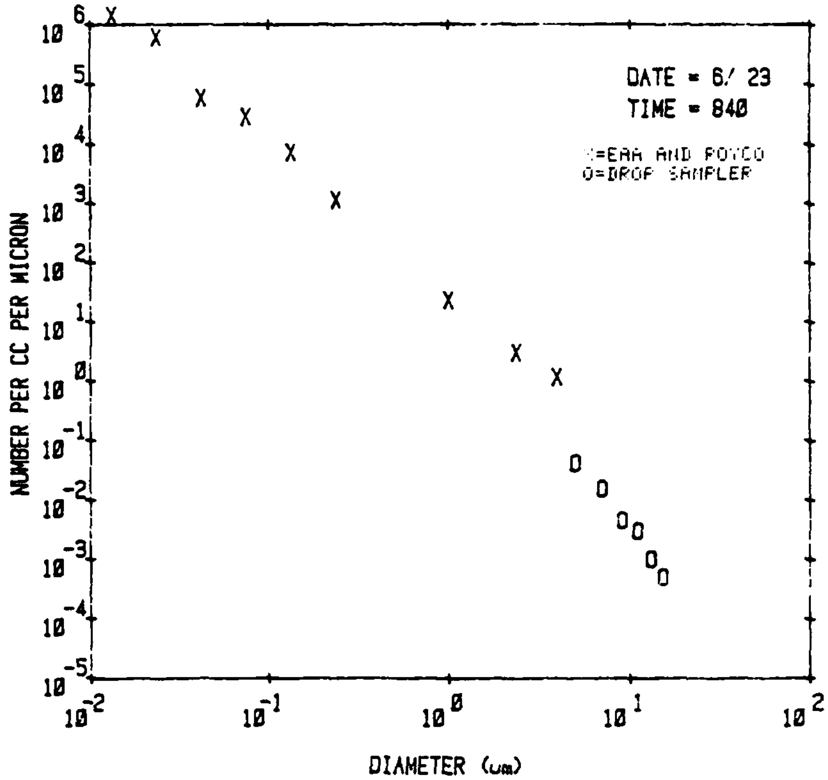
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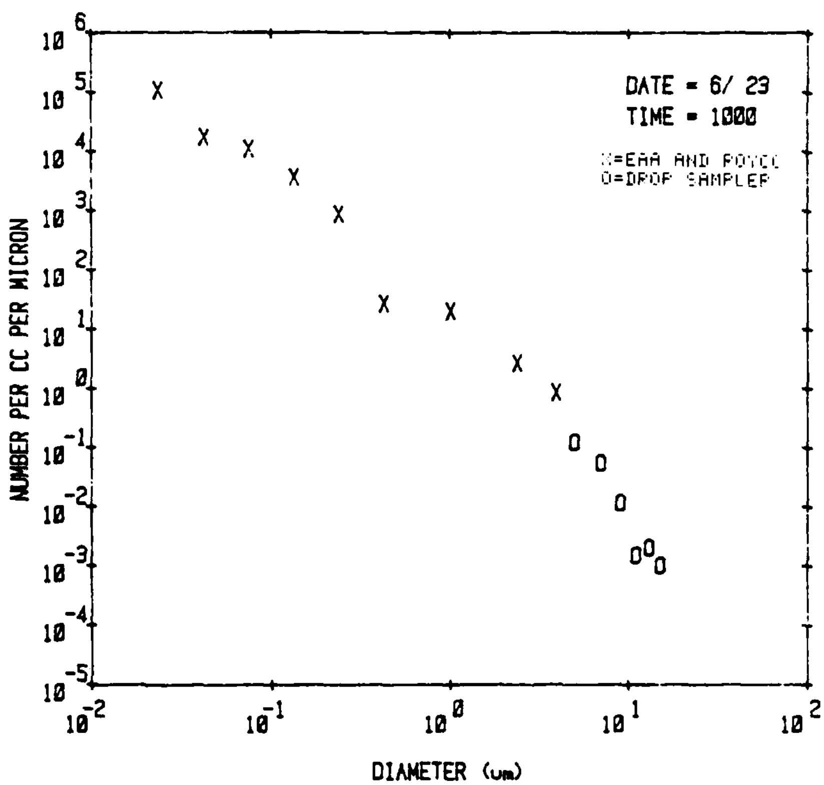
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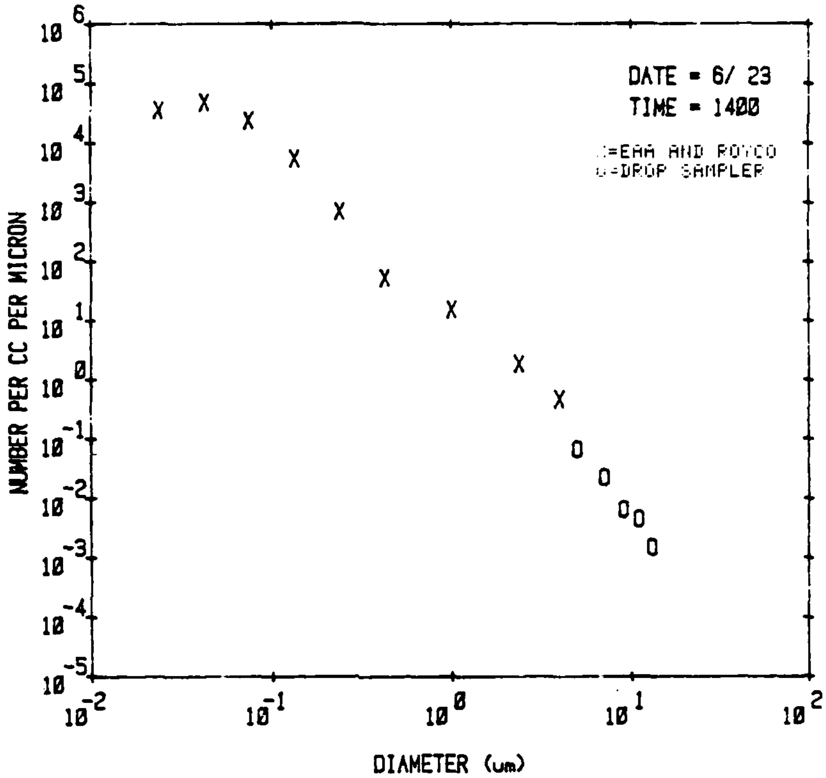
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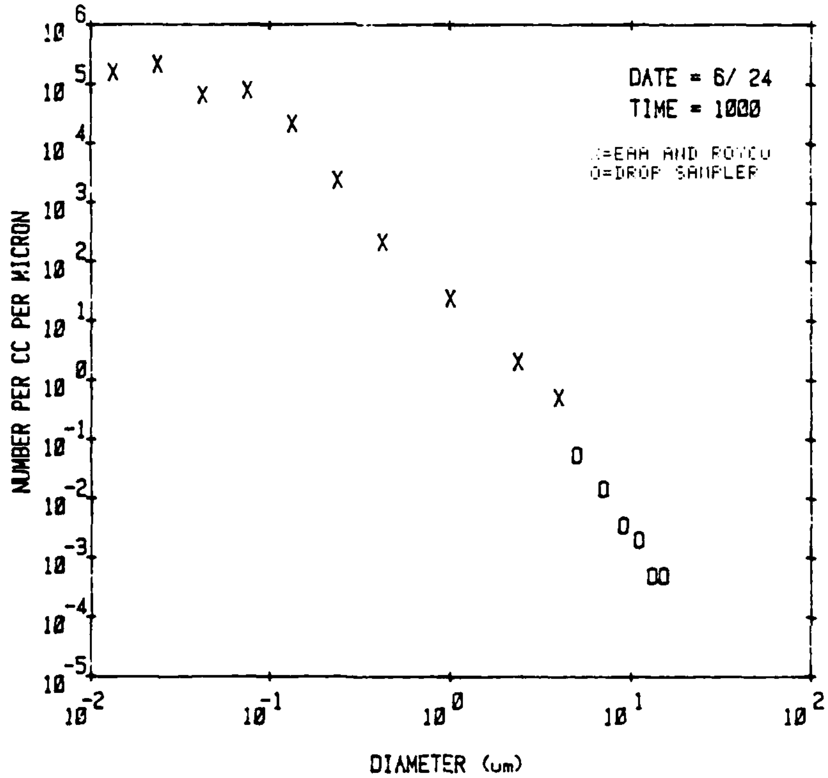
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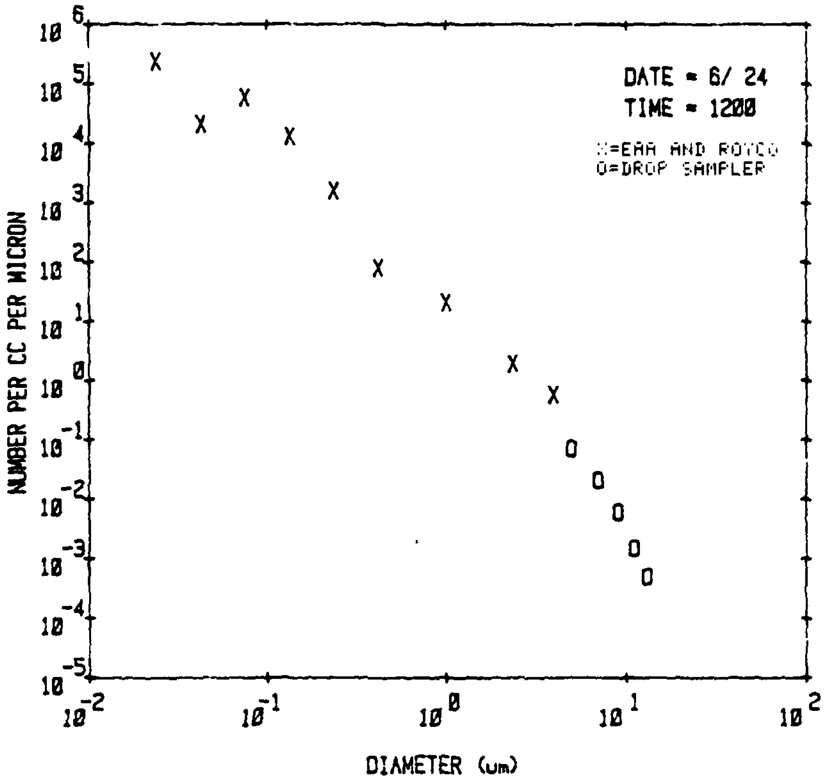
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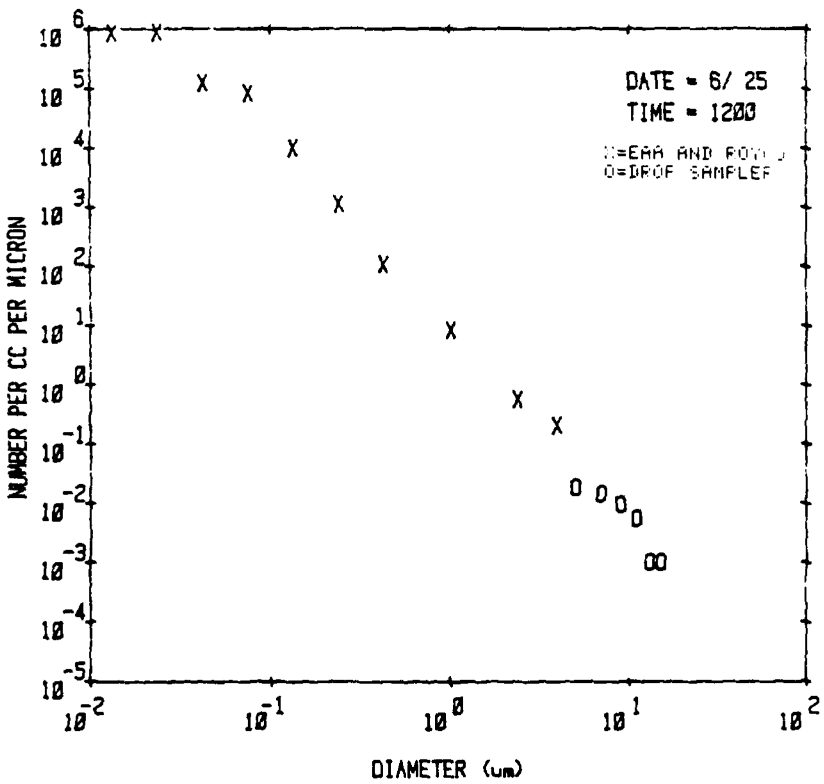
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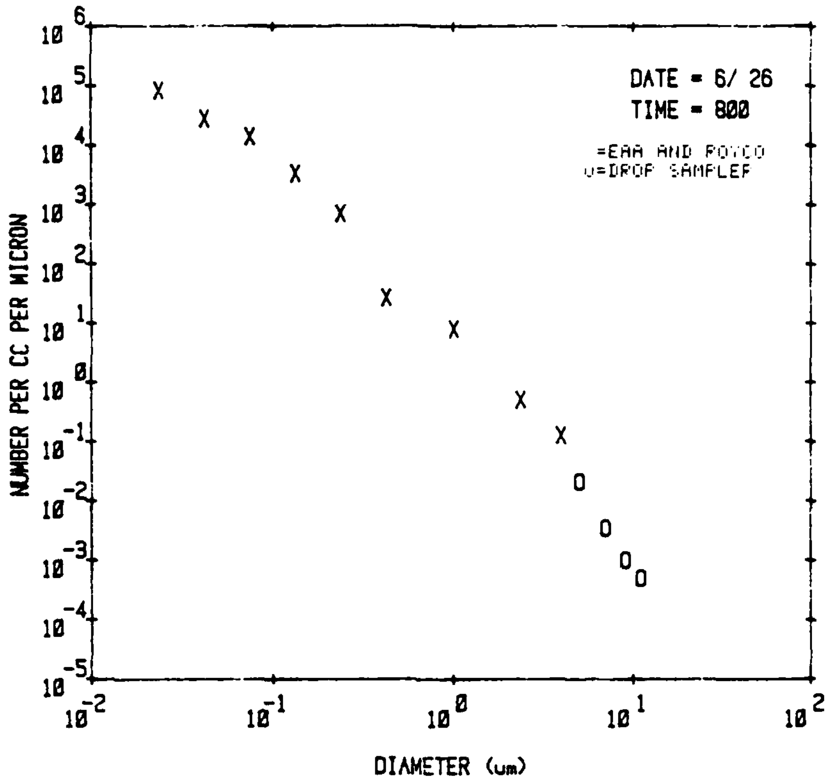
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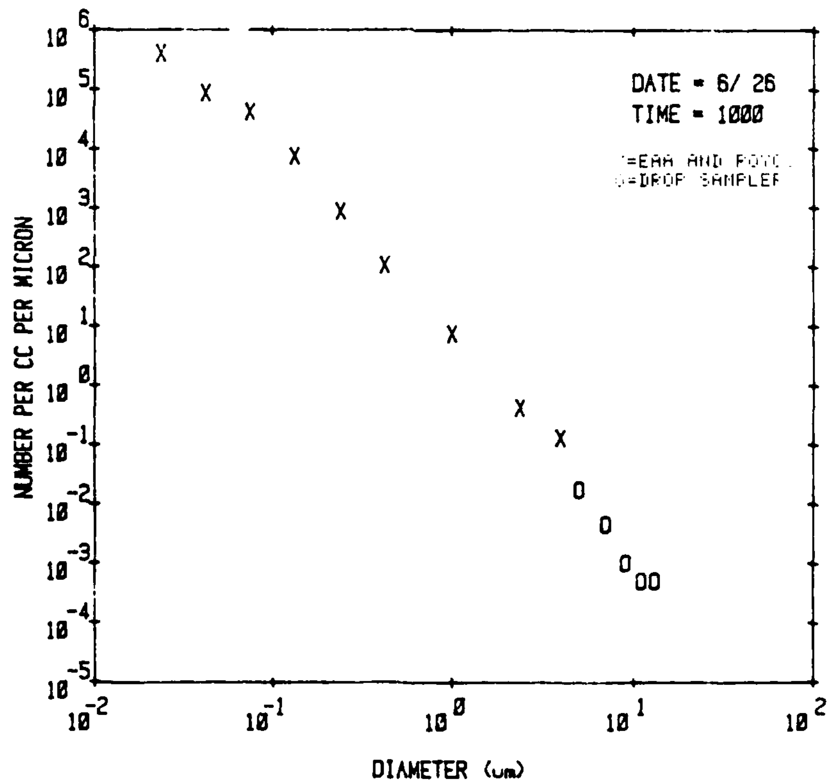
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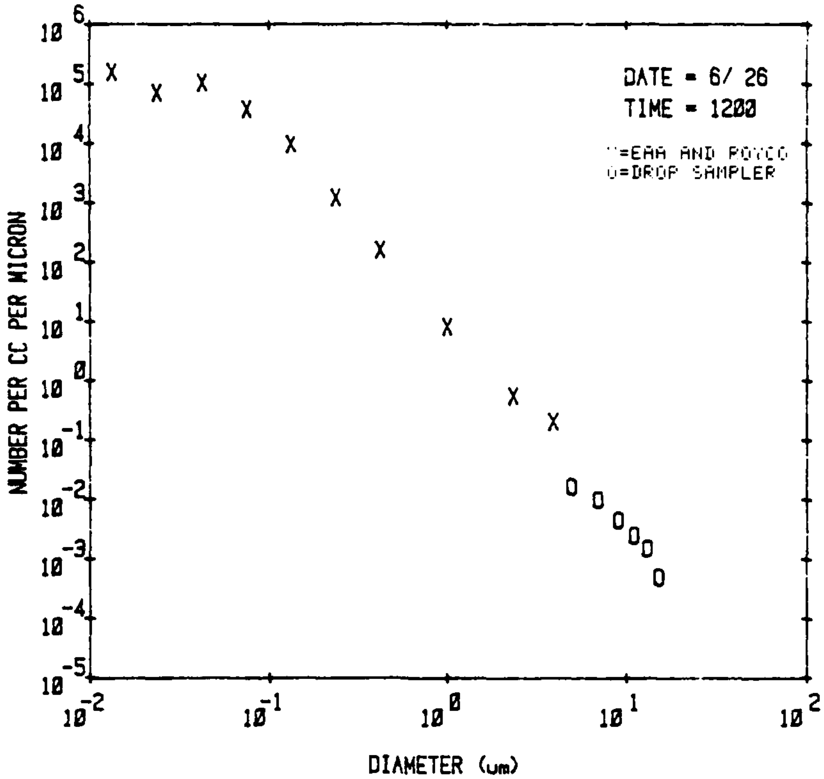
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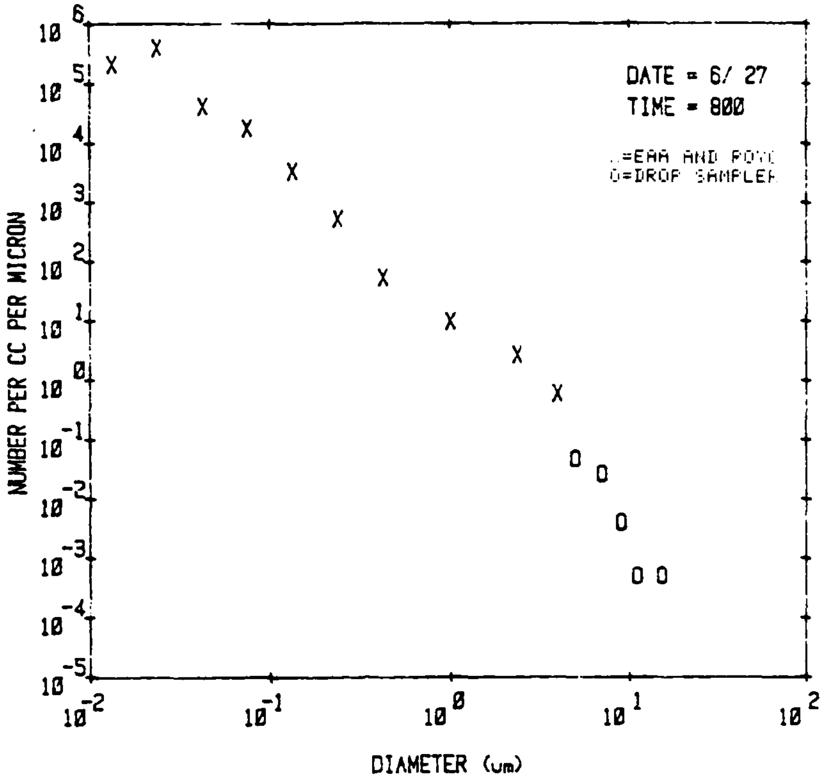
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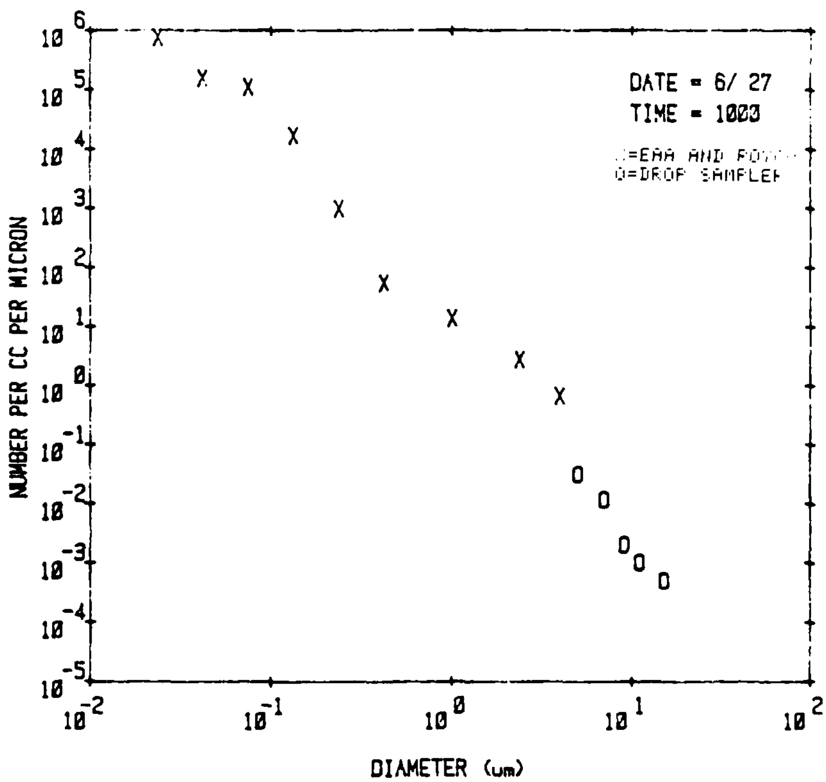
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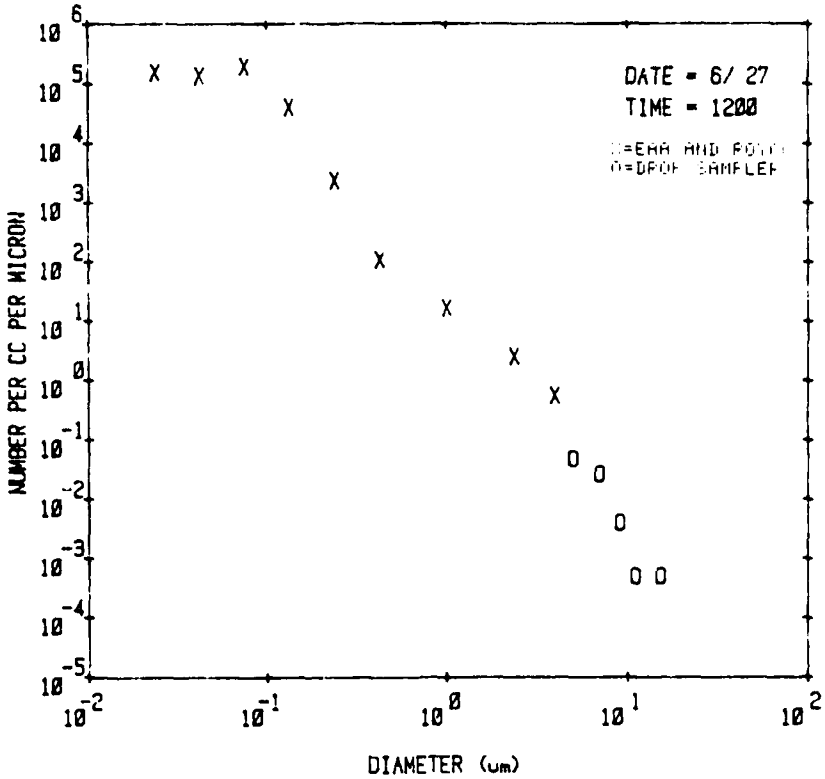
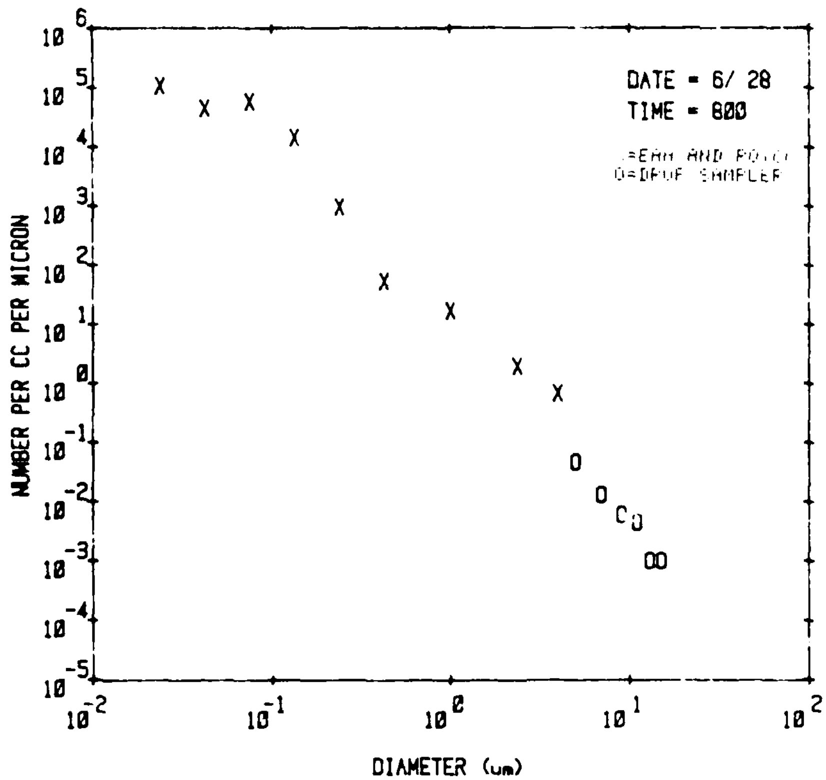
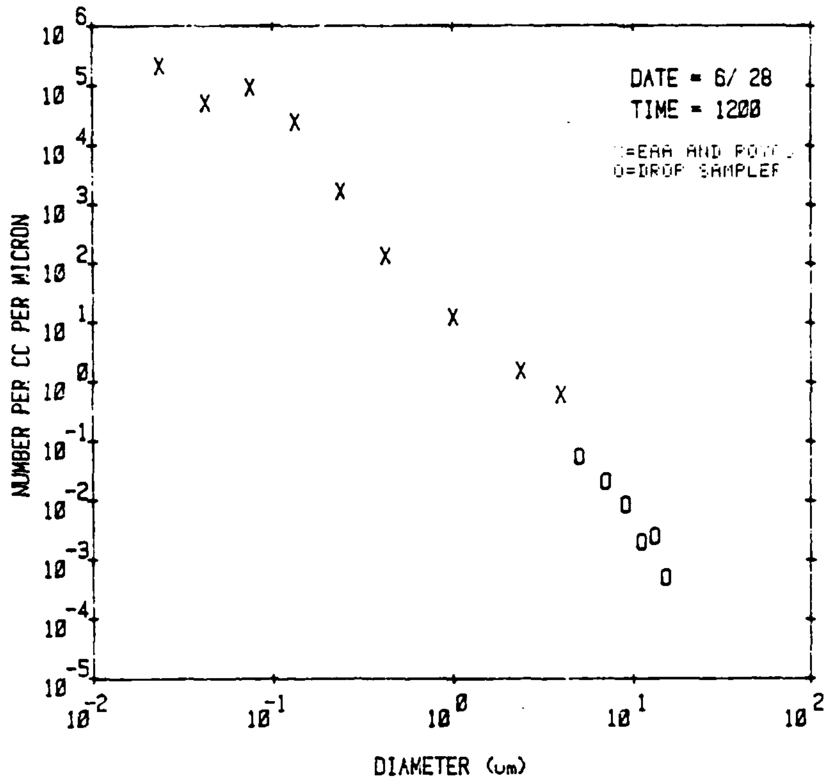
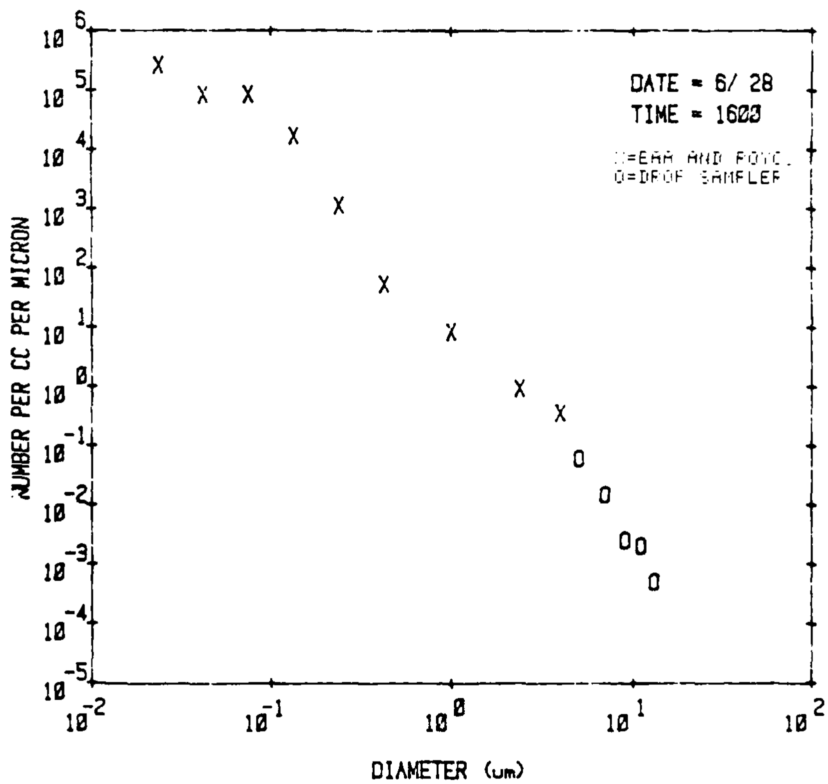
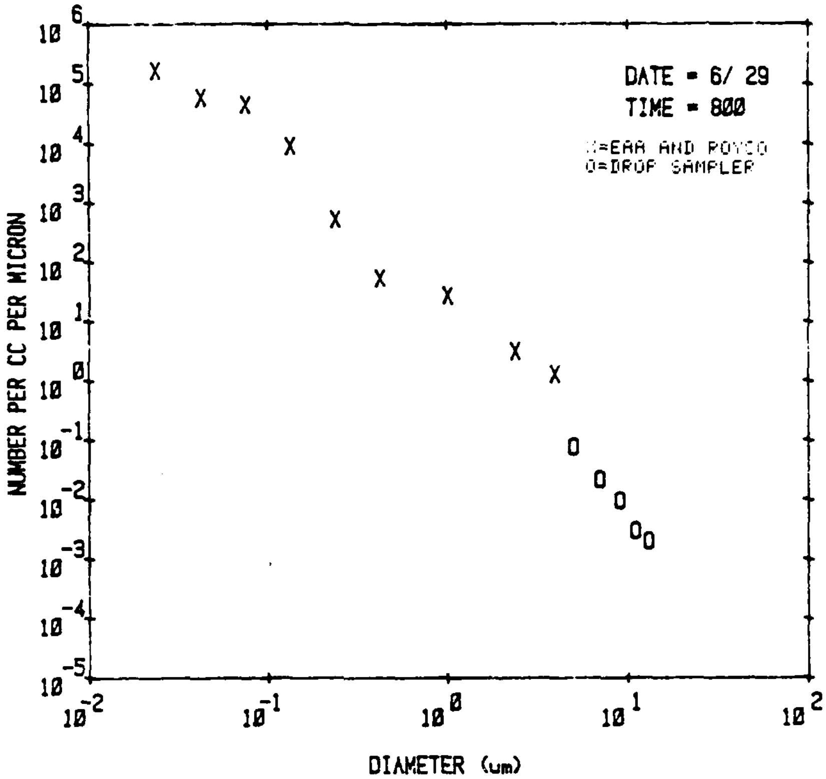
DIAMETER (um)

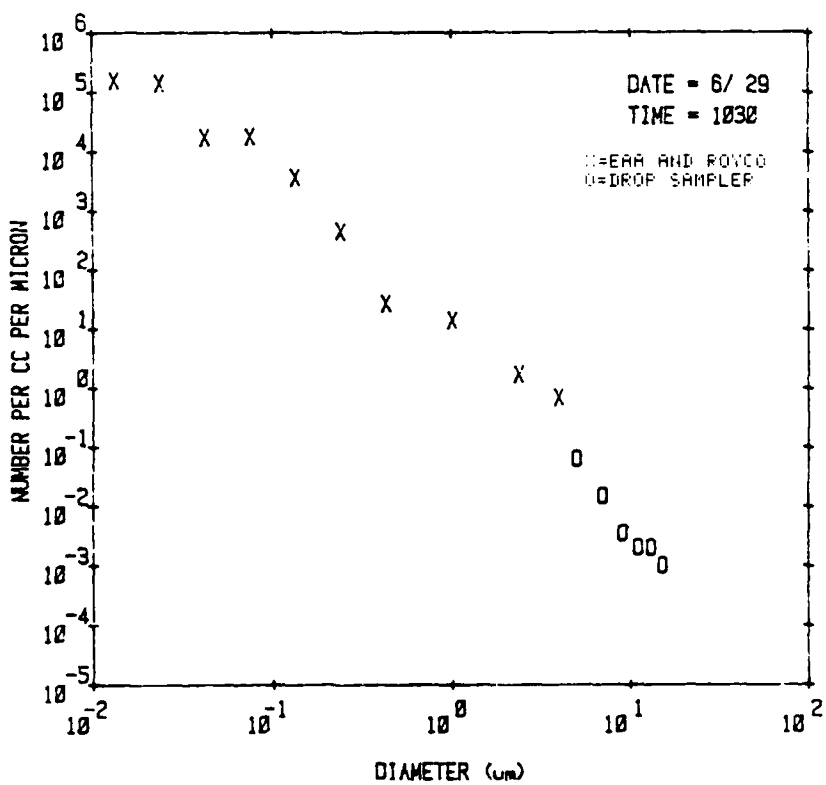

DATE = 6/ 27
TIME = 1200
NUMBER PER CC PER MICRON
DIAMETER (um)

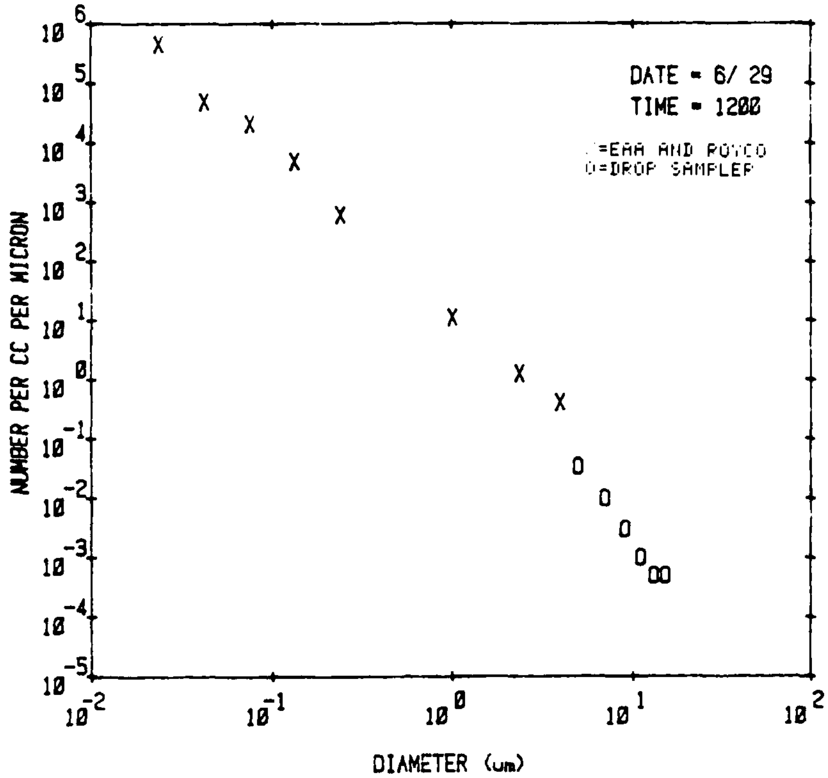

DATE = 6/ 28
TIME = 800
NUMBER PER CC PER MICRON
DIAMETER (um)

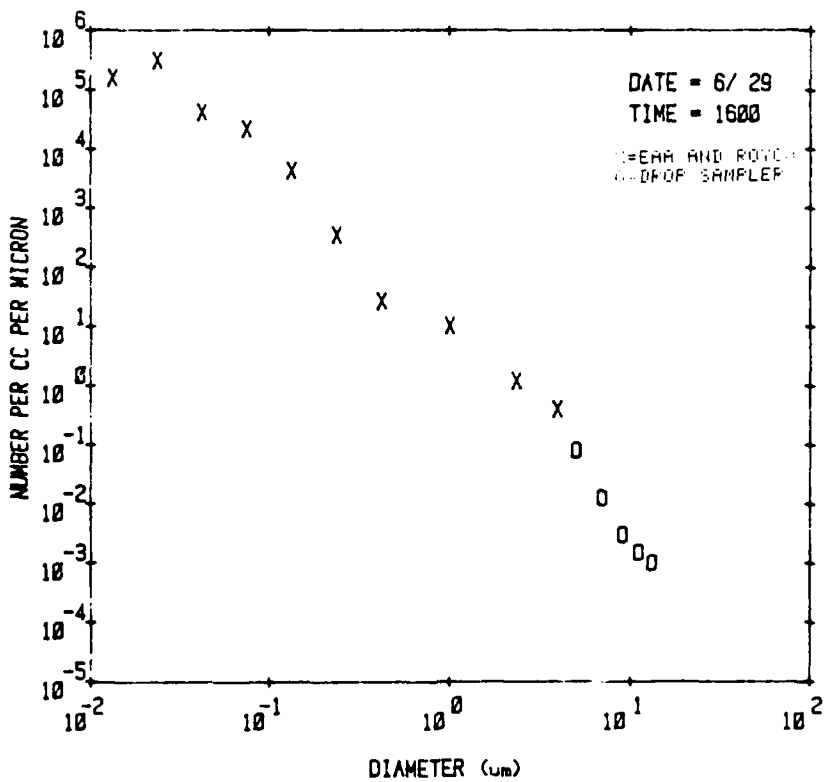

DATE = 6/ 28
TIME = 1200
X=EAA AND ROYCO
O=DROP SAMPLER
NUMBER PER CC PER MICRON
DIAMETER (um)


DATE = 6/ 28
TIME = 1600
X=EAA AND ROYCO
O=DROP SAMPLER
NUMBER PER CC PER MICRON
DIAMETER (um)


DATE = 6/ 29
TIME = 800
X=EAA AND ROYCO
O=DROP SAMPLER
NUMBER PER CC PER MICRON
DIAMETER (um)


DATE = 6/ 29
TIME = 1030
X=EAA AND ROYCO
O=DROP SAMPLER
NUMBER PER CC PER MICRON
DIAMETER (um)


DATE = 6/ 29
TIME = 1200
X=EAA AND ROYCO
O=DROP SAMPLER
NUMBER PER CC PER MICRON
DIAMETER (um)


DATE = 6/ 29
TIME = 1600
X=EAA AND ROYCO
O=DROP SAMPLER
NUMBER PER CC PER MICRON
DIAMETER (um)

USNS LYNCH PARTICLE SIZE DISTRIBUTION

(Number of particles per cm^3 per size interval)

JUNE 17, 1986 — Particle Diameter (microns)

GMT TIME	.01 .018	.018 .032	.032 .056	.056 .100	.100 .178	.178 .316	.316 0.56	0.56 1.78	1.78 3.16	3.16 5.62	5.62 10.0	Total
[illegible]	1251	[illegible]	522	1288	868	320	60	140	129.3	6.7	[illegible]	5419
1000	1668	334	1218	888	940	308	47	70	130.6	6.5	0.1	5609
1100	0	501	870	1199	916	295	60	75	145.3	7.0	0.1	4069
1200	0	1503	957	1776	1181	344	53	333	128.6	7.4	0.1	6283
1300	0	167	522	710	1036	258	47	347	81.1	7.8	0.1	3177
1400	0	1837	783	1332	988	308	47	226	62.1	7.3	0.1	5590
1500	0	501	522	1820	1157	344	40	327	76.5	6.8	0.1	4795
1600	0	668	348	1243	1060	308	47	25	86.3	6.5	0.1	3792
1700	1668	0	609	932	1036	320	60	84	90.7	6.6	0.1	4807
1800	834	334	174	710	916	308	60	73	84.2	7.5	0.1	3500
1900	1668	334	783	1243	1085	332	53	0	0.0	0.0	0.0	5498

JUNE 18, 1986

600	2085	1002	870	1998	1542	431	67	0	0.0	0.0	0.0	7995
700	0	1837	957	2797	2338	590	60	0	0.0	0.0	0.0	8579
800	0	3173	2001	3952	2555	615	67	0	0.0	0.0	0.0	12362
900	834	2505	1479	2176	1567	467	60	111	11.1	0.9	0.1	9210
1030	1251	835	435	844	1012	418	60	89	3.1	0.5	0.0	4947
1100	417	334	348	799	1036	344	60	90	3.0	0.9	0.0	3433
1200	417	0	435	666	892	381	53	86	2.6	0.5	0.0	2933
1300	0	9686	3654	3774	1808	443	67	70	2.8	0.7	0.0	19504
1400	417	668	1914	2131	1350	418	60	81	3.0	1.2	0.0	7043
1500	0	0	0	0	0	0	0	72	3.3	1.4	0.0	77
1630	1251	2338	1827	3907	2362	492	67	783	5.5	1.3	0.0	13034
1700	0	0	0	0	0	0	0	87	6.2	2.4	0.0	95
1800	0	0	0	0	0	0	0	59	3.9	1.5	0.0	65
1900	0	668	783	1776	1205	369	53	49	2.7	0.8	0.0	4906

JUNE 19, 1986

600	3336	10020	1653	1909	1808	603	80	108	8.5	1.2	0.0	19527
650	0	167	609	1288	1374	664	120	0	0.0	0.0	0.0	4222
700	834	501	522	1510	1277	578	127	163	10.4	1.2	0.0	5523
800	16263	167	1392	3108	2145	689	160	161	10.3	1.1	0.0	24096
900	17097	4509	1914	1687	1374	566	67	78	5.6	1.0	0.0	27298
1011	417	501	957	1598	1205	418	67	59	4.2	1.0	0.0	5228
1038	0	0	0	0	0	0	0	46	3.4	0.9	0.0	51
1100	0	1336	783	1776	1301	369	40	50	3.5	0.9	0.0	5659
1215	0	334	609	2664	96	295	33	54	3.4	0.8	0.0	4090
1300	0	1336	1044	1909	1060	344	53	57	3.6	0.9	0.0	5809
1400	417	501	609	1199	892	295	47	39	2.4	0.6	0.0	4001
1500	0	0	0	0	0	0	0	40	1.8	0.6	0.0	42
1600	1251	334	1131	2486	1856	480	73	88	3.8	0.6	0.0	7704
1700	1668	4676	2088	3286	1952	590	107	148	7.5	0.8	0.0	14523

USNS LYNCH PARTICLE SIZE DISTRIBUTION

(Number of particles per cm^3 per size interval)

JUNE 20,1986 — Particle Diameter (microns)

GMT TIME	.01 .018	.018 .032	.032 .056	.056 .100	.100 .178	.178 .316	.316 0.56	0.56 1.78	1.78 3.16	3.16 5.62	5.62 10.0	Total
[illegible]	2085	[illegible]	1044	1820	1326	[illegible]	47	230	26.6	1.5	0.0	9516
700	2502	3674	1392	1732	1326	369	40	200	13.0	1.1	0.0	11248
800	0	2171	609	1199	747	271	40	49	3.6	1.5	0.0	5091
900	0	668	696	1332	723	209	33	42	2.7	1.0	0.0	3707
1000	2085	1670	870	1199	603	160	27	24	2.4	1.3	0.0	6649
1100	2502	1837	1044	1243	482	111	27	19	2.4	1.3	0.0	7268
1215	0	1503	783	89	169	86	0	14	1.6	0.8	0.0	2645
1320	0	6847	2088	1154	386	62	0	15	1.7	0.8	0.0	10554
1415	417	6513	3393	2087	506	98	13	15	1.4	0.6	0.0	13044
1500	417	3340	3219	3019	747	123	20	18	1.6	0.8	0.0	10906
1614	3753	3507	4437	3419	603	74	7	9	0.9	0.2	0.0	15809
1716	30024	6680	10962	3463	506	62	27	26	2.8	2.1	0.0	51754
1809	56712	3006	1218	1776	289	62	0	26	2.8	2.1	0.0	63093
1818	0	3674	1827	1110	241	49	0	0	0.0	0.0	0.0	6901

JUNE 21,1986

500	7506	12525	1479	622	241	37	7	14	1.8	1.1	0.0	22433
600	1251	1503	609	622	217	25	7	11	1.4	0.8	0.0	4246
700	7089	835	783	488	337	37	7	11	1.4	0.8	0.0	9590
800	22935	8350	1131	888	337	62	7	11	1.2	0.7	0.0	33722
900	834	1670	348	755	265	62	7	11	1.1	0.6	0.0	3952
933	0	1336	1218	1021	313	74	13	11	1.3	0.6	0.0	3989
1030	0	1837	783	932	337	98	7	10	1.1	0.6	0.0	4007
1100	417	1336	696	888	410	123	13	13	1.4	0.7	0.0	3898
1200	0	1503	783	1021	482	74	13	10	1.1	0.5	0.0	3888
1300	0	1169	522	755	313	74	7	10	1.2	0.5	0.0	2851
1400	417	668	522	400	193	62	0	10	1.1	0.5	0.0	2272
1500	417	835	348	222	145	62	0	9	0.8	0.2	0.0	2038
1600	417	501	696	311	145	62	7	9	1.0	0.3	0.0	2148
1700	0	334	435	710	289	98	7	10	1.0	0.4	0.0	1885
1800	0	835	348	533	241	62	7	10	1.0	0.2	0.0	2036

JUNE 22,1986

520	417	501	261	533	299	74	0	14	1.3	0.3	0.0	2091
600	834	167	261	400	169	74	7	9	0.9	0.2	0.0	1921
700	0	2171	522	355	193	49	7	14	1.2	0.5	0.0	3313
800	15012	5010	174	533	193	74	7	13	1.2	0.4	0.0	21016
900	8757	15364	1131	666	289	62	7	11	1.4	0.6	0.0	26289
1019	0	0	0	0	0	0	0	12	1.5	0.8	0.0	15
1100	1668	13360	3393	1598	410	74	7	13	1.5	0.8	0.0	20524
1200	6255	7181	2610	1598	362	49	13	12	1.4	0.8	0.0	18083
1300	2502	6179	2088	1199	337	49	13	13	1.8	1.0	0.0	12384
1400	1251	3173	1392	2176	723	86	7	16	2.2	1.4	0.0	8827
1500	1251	1503	609	755	289	74	7	15	1.5	0.6	0.0	4505
1600	417	167	348	1066	337	86	7	13	1.7	0.7	0.0	244[illegible]
1700	0	0	522	622	337	135	0	14	1.9	0.9	0.0	16[illegible]
1800	5004	835	696	799	362	123	7	14	1.6	0.8	0.0	78[illegible]

USNS LYNCH PARTICLE SIZE DISTRIBUTION

(Number of particles per cm^3 per size interval)

JUNE 23,1986 — **Particle Diameter (microns)**

GMT TIME	.01 .018	.018 .032	.032 .056	.056 .100	.100 .178	.178 .316	.316 0.56	0.56 1.78	1.78 3.16	3.16 5.62	5.62 10.0	Total
530	417	83[illegible]	261	355	1[illegible]	86	7	15	1.6	0.3		2171
600	2085	7348	1653	2398	7[illegible]	135	13	17	1.7	0.6		14398
700	3753	5010	957	1199	456	111	13	22	2.6	1.1	0.0	11526
840	11259	8517	1479	1288	578	160	0	28	4.1	2.2	0.0	23315
1000	0	1503	435	488	289	123	7	25	3.7	1.6	0.0	2875
1100	0	668	522	844	410	111	7	23	3.2	1.6	0.0	2589
1200	1251	3340	1131	1776	554	111	27	22	3.1	1.4	0.0	8216
1300	834	2672	2088	2264	795	148	13	18	2.5	0.9	0.0	8837
1400	0	501	1218	1066	434	98	13	19	2.5	0.9	0.0	3353
1500	417	835	435	622	265	98	13	21	3.0	1.0	0.0	2711
1600	417	1336	1044	1154	506	160	20	20	2.5	0.9	0.0	4661
1700	4170	0	1740	844	217	74	27	17	2.5	1.1	0.0	7092
1800	834	1670	609	710	386	98	27	17	1.9	0.8	0.0	4353

JUNE 24,1986

GMT TIME	.01 .018	.018 .032	.032 .056	.056 .100	.100 .178	.178 .316	.316 0.56	0.56 1.78	1.78 3.16	3.16 5.62	5.62 10.0	Total
640	417	4509	1914	2309	892	172	33	35	2.9	1.2	0.0	10285
700	0	2672	1218	1909	916	185	33	32	2.8	1.2	0.0	6968
800	5004	2672	1305	1820	651	160	27	29	3.0	1.1	0.0	11672
900	3753	4008	2436	3064	1205	234	47	40	3.4	1.3	0.0	14790
1000	1251	3006	1653	3508	1711	332	53	29	2.9	0.9	0.0	11547
1100	4587	7181	1479	2575	1157	258	53	29	2.8	1.2	0.0	17324
1200	0	3340	522	2620	1036	221	20	26	2.7	1.1	0.0	7789
1300	4170	3841	2262	1687	699	148	13	26	2.2	1.0	0.0	12849
1600	0	5845	2958	1820	554	111	7	23	2.0	0.9	0.0	11321
1700	417	5010	3306	2442	651	135	7	24	1.7	0.8	0.0	11994
1800	417	1503	1395	2975	1157	148	40	21	1.3	0.5	0.0	7567

JUNE 25,1986

GMT TIME	.01 .018	.018 .032	.032 .056	.056 .100	.100 .178	.178 .316	.316 0.56	0.56 1.78	1.78 3.16	3.16 5.62	5.62 10.0	Total
600	834	2004	957	1021	386	98	7	22	2.5	1.2	0.0	5332
700	2502	3841	1305	2087	651	135	7	40	4.1	2.2	0.0	10574
800	834	1670	957	977	265	111	0	22	2.9	1.2	0.0	4839
900	417	835	522	488	193	62	7	14	1.9	0.9	0.0	2540
1000	9591	4676	2697	2708	771	148	13	14	1.7	0.9	0.0	20621
1100	1251	4008	1566	1554	530	74	13	11	1.3	0.6	0.0	9009
1200	6672	12358	3132	3730	795	160	27	10	0.8	0.4	0.0	26885
1300	11676	2672	1740	2620	771	172	27	13	0.9	0.4	0.0	19692
1400	0	2839	1479	1021	410	111	27	8	0.8	0.4	0.0	5896
1500	46287	13193	1392	4307	1542	308	40	11	0.8	0.4	0.0	67081
1516	0	8183	5394	6305	1398	160	27	0	0.0	0.0	0.0	21466
1600	834	1169	1827	3286	1133	160	13	16	0.9	0.4	0.0	8438
1700	0	3173	3741	4174	1109	160	20	11	1.1	0.5	0.0	12388
1800	417	1503	1305	3552	1398	172	27	12	1.1	0.4	0.0	8387

USNS LYNCH PARTICLE SIZE DISTRIBUTION

(Number of particles per cm^3 per size interval)

JUNE 2[illegible] [illegible]6 — Particle Diameter (microns)

GMT TIME	.01 .018	.018 .032	.032 .056	.056 .100	.100 .178	.178 .316	.316 0.56	0.56 1.78	1.78 3.16	3.16 5.62	5.62 10.0	Total
600	0	3006	1914	1820	6[illegible]	123	13	9	9	0.3	0.0	7490
800	0	1169	696	622	2[illegible]	98	7	10	0.7	0.2	0.0	2867
900	3	1503	1044	1110	362	111	7	9	0.8	0.3	0.0	4146
1000	0	5678	2175	1865	603	123	27	9	0.6	0.2	0.0	10480
1100	0	1670	1131	1598	554	160	33	10	0.6	0.2	0.0	5158
1200	1251	1002	2610	1687	771	172	40	10	0.8	0.4	0.0	7545
1300	0	668	348	2442	988	209	40	14	0.8	0.3	0.0	4711
1400	0	2004	522	1199	506	123	27	11	0.9	0.3	0.0	4392
1500	5421	1837	696	799	410	98	13	9	1.1	0.6	0.0	9286
1600	417	1336	348	710	410	111	13	9	0.7	0.5	0.0	3355
1700	0	1503	609	1066	603	123	13	9	0.8	0.4	0.0	3926

JUNE 27, 1986

600	1668	2004	696	799	362	98	7	13	1.3	0.5	0.0	5648
700	2919	2505	870	932	434	111	20	15	1.4	0.7	0.0	7808
800	1668	5511	1044	799	265	74	13	12	3.7	1.1	0.0	9391
900	3753	7181	2436	2797	747	98	7	16	4.1	1.3	0.0	17041
1000	0	10521	3915	4928	1326	135	13	17	3.8	1.2	0.0	20860
1100	0	5678	5481	9280	2988	320	20	24	4.4	1.1	0.0	23796
1200	0	2171	3393	8658	3229	332	27	20	3.5	1.0	0.0	17835
1300	0	3841	9048	13853	2916	160	40	16	3.6	1.3	0.0	29879
1400	834	3841	5220	8347	2024	209	33	16	4.2	1.7	0.0	20531
1500	5421	4676	2784	2486	1036	86	7	17	3.7	1.5	0.0	16518
1600	0	3674	3306	4218	1133	148	13	16	4.0	1.5	0.0	12513
1700	0	3674	3480	4795	1205	148	7	15	3.6	1.2	0.0	13328
1800	834	2171	4002	6038	1422	135	20	12	3.4	1.3	0.0	14640

JUNE 28, 1986

600	5838	1169	1131	2886	1229	123	27	22	5.0	1.8	0.0	12432
700	0	1670	957	2042	771	74	27	23	3.3	1.7	0.0	5569
800	0	1503	1131	2575	1133	135	13	21	2.7	1.3	0.0	6515
900	0	2839	1305	2797	940	123	0	27	3.9	1.7	0.0	8037
1000	0	1503	1044	3019	1085	123	7	25	3.3	1.4	0.0	6810
1100	0	1002	1305	3463	1470	209	13	20	2.5	1.3	0.0	7486
1200	0	3006	1305	4218	1976	234	33	15	2.2	1.1	0.0	10791
1300	834	2338	2088	3064	1085	160	7	15	1.9	1.1	0.0	9592
1400	0	2505	1653	2842	868	135	13	11	1.4	0.7	0.0	8029
1500	4170	4342	2175	4262	2024	197	27	11	1.3	0.8	0.0	17210
1600	0	3674	2088	3730	1350	160	13	10	1.3	0.7	0.0	11027
1700	0	3674	1827	2486	699	86	7	8	0.9	0.4	0.0	8788
1800	834	2505	2175	3952	1301	160	13	8	0.8	0.4	0.0	10949

USNS LYNCH PARTICLE SIZE DISTRIBUTION

(Number of particles per cm^3 per size interval)

JUNE 2[illegible],1986 Particle Diameter (microns)

GMT TIME	.01 .018	.018 .032	.032 .056	.056 .100	.100 .178	.178 .316	.316 0.56	0.56 1.78	1.78 3.16	3.16 5.62	5.62 10.0	Total
800	0	2338	1479	1998	723	[illegible]	13	33	4.3	2.4	0.0	6665
900	3753	13527	1914	2309	699	86	7	17	2.2	1.1	0.0	22315
915	5838	10187	1305	2042	675	111	7	0	0.0	0.0	0.0	20165
940	0	4342	1392	1643	627	49	13	17	2.2	1.3	0.0	8086
1030	1251	2004	435	799	289	62	7	17	2.4	1.3	0.0	4868
1100	6672	3674	957	844	337	74	7	17	2.0	1.1	0.0	12585
1200	0	6346	1218	932	386	86	0	14	1.7	0.7	0.0	8984
1340	2919	2171	522	755	337	86	0	10	1.2	0.5	0.0	6802
1410	0	2672	696	977	217	74	0	9	1.1	0.5	0.0	4646
1500	0	16867	2610	1332	795	98	7	12	1.7	0.8	0.0	21724
1600	1251	4342	1644	977	337	49	7	13	1.7	0.7	0.0	8022

DROP SIZE DISTRIBUTION - USNS LYNCH

(Number of droplets per cm^3 per size interval)

[illegible] 19,1986

Particle Diameter (microns)

GMT TIME	2-4	4-6	6-8	8-10	10-12	12-14	14-16	16-18	18-20	20-22
[illegible]00	0.139	0.036	0.007	.001	0.000	[illegible]	0.000	0.000	.00[illegible]	0.000
1011	0.085	0.031	0.013	0.008	0.002	0.003	0.001	0.001	0.001	0.000
1215	0.093	0.025	0.007	0.003	0.002	0.000	0.001	0.001	0.000	0.001

JUNE 20,1986

800	0.108	0.058	0.019	0.006	0.002	0.002	0.000	0.000	0.000	0.000
1000	0.078	0.046	0.017	0.014	0.003	0.003	0.002	0.001	0.000	0.000
1215	0.094	0.023	0.010	0.005	0.002	0.000	0.000	0.001	0.000	0.001

JUNE 21,1986

800	0.083	0.025	0.006	0.005	0.002	0.001	0.001	0.000	0.000	0.000
1030	0.116	0.029	0.008	0.004	0.004	0.001	0.001	0.000	0.000	0.000
1200	0.193	0.028	0.005	0.003	0.002	0.000	0.001	0.000	0.000	0.000

JUNE 22,1986

800	0.097	0.030	0.006	0.003	0.002	0.001	0.000	0.000	0.000	0.000
1100	0.124	0.029	0.010	0.003	0.002	0.000	0.000	0.000	0.000	0.000
1200	0.083	0.012	0.005	0.001	0.001	0.001	0.000	0.000	0.000	0.000

JUNE 23,1986

0	0.083	0.031	0.000	0.009	0.006	0.002	0.001	0.001	0.000	0.000
840	0.083	0.031	0.009	0.006	0.002	0.001	0.001	0.000	0.000	0.000
1000	0.248	0.109	0.023	0.003	0.004	0.002	0.001	0.000	0.000	0.000
1400	0.134	0.045	0.013	0.009	0.003	0.000	0.001	0.000	0.001	0.000

DROP SIZE DISTRIBUTION - USNS LYNCH

(Number of droplets per cm^3 per size interval)

Particle Diameter (microns)

GMT TIME	2-4	4-6	6-8	8-10	10-12	12-14	14-16	16-18	18-20	20-22
JUNE 24,198										
1000	0.109	0.029	[illegible]	0.004	[illegible]	0.001	[illegible]	[illegible]	[illegible]	[illegible]
1200	0.142	0.041	0.012	0.003	0.001	0.000	0.002	0.001	0.000	[illegible]
JUNE 25,1986										
1200	0.037	0.029	0.019	0.011	0.002	0.002	0.001	0.000	0.000	0.000
JUNE 26,1986										
800	0.042	0.007	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000
1000	0.035	0.009	0.002	0.001	0.001	0.000	0.000	0.000	0.000	0.000
1200	0.033	0.020	0.009	0.005	0.003	0.001	0.000	0.001	0.000	0.000
JUNE 27,1986										
800	0.095	0.053	0.008	0.001	0.000	0.001	0.000	0.000	0.001	0.000
1000	0.062	0.023	0.004	0.002	0.000	0.001	0.000	0.000	0.000	0.000
1200	0.095	0.053	0.008	0.001	0.000	0.001	0.000	0.000	0.001	0.000
1600	0.162	0.035	0.012	0.010	0.005	0.004	0.001	0.001	0.001	0.000
JUNE 28,1986										
800	0.093	0.026	0.012	0.009	0.002	0.002	0.000	0.000	0.001	0.000
1200	0.111	0.042	0.017	0.004	0.005	0.001	0.001	0.000	0.000	0.000
1600	0.120	0.029	0.005	0.004	[illegible]	0.000	0.000	0.000	0.000	0.000
JUNE 29,1986										
800	0.154	0.043	0.019	0.006	0.004	0.000	0.002	0.001	0.000	0.000
1030	0.127	0.030	0.007	0.004	0.004	0.002	0.000	0.000	0.000	0.000
1200	0.068	0.020	0.006	0.002	0.001	0.001	0.001	0.000	0.000	0.000
1600	0.159	0.025	0.006	0.003	0.002	0.000	0.000	0.000	0.000	0.000

PERCENT OF PARTICLES CONTAINING INDICATED ELEMENT

USNS LYNCH CRUISE

Date	GMT Time	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	Fe
6/19	1006	4	6	6	16	0	4	44	38	24	4	4
6/19	1220	0	8	46	60	0	14	2	32	18	0	26
6/20	1004	6	8	96	52	0	26	20	20	6	0	6
6/20	1213	24	12	52	58	0	0	42	24	8	2	12
6/21	1011	46	6	100	18	2	6	66	10	6	2	2
6/21	1211	12	10	22	34	0	6	30	12	16	0	2
6/22	1018	40	14	58	36	6	0	38	10	6	4	12
6/22	1213	8	4	16	20	0	4	8	12	12	2	8
6/23	0838	0	4	22	18	0	0	42	14	22	2	6
6/23	1023	12	6	42	36	2	2	20	4	18	0	4
6/23	1216	22	4	22	24	0	2	54	0	14	0	6
6/24	1119	4	0	12	18	8	96	0	8	10	32	10
6/24	1205	4	2	18	26	0	0	0	12	0	0	8
6/25	1158	26	6	40	46	8	52	2	22	2	2	22
6/26	0959	34	14	34	46	0	40	2	16	16	4	20
6/26	1208	22	8	30	32	0	26	20	16	4	0	14
6/27	0958	26	24	28	48	2	8	24	16	30	12	14
6/27	1210	10	6	28	30	2	14	0	16	4	16	12
6/28	1000	72	34	16	18	2	36	16	10	14	0	12
6/28	1200	20	14	38	46	0	8	4	20	6	0	20
6/29	1003	20	2	38	42	0	6	0	12	10	0	6
6/29	1221	32	20	46	50	0	12	10	38	18	0	28

APPENDIX C
OPTICAL DEPTH COMPUTATION TECHNIQUE

During the Gibraltar Experiment, sun photometry data were acquired at hourly intervals, when possible, during the cruise. Data were obtained for a 5 nm wide band centered at 502nm. For a narrow wavelength band, such as prescribed by the 502nm filter, aerosol optical thickness can be computed from sun photometer measurements by:

$$\tau_A = \frac{1}{M}\left[\ln I_o - \ln I - \ln F - (\tau_R + \tau_o) K M \frac{p}{p_o}\right]$$

(From Volz: Sun Photometer Instructions)

τ_A = aerosol optical depth at M = 1

M = sec (z) where z is the solar zenith angle

I_o = solar radiation at top of earth's atmosphere and mean solar distance

I = observed solar radiation

F = correction factor for distance to sun at observation time relative to mean solar distance

τ_R = Rayleigh optical thickness (scattering by atmospheric gases) at standard pressure, p = 1013 mb

τ_o = Ozone optical thickness (gaseous absorption) at standard pressure

p = observed surface pressure

K = correction factor to τ_R and τ_o when $M>1$ (supplied by Volz)

From Hoyt, D.V. (J. Appl. Met. 16 p. 432, 1977):

τ_R = .1402 for June and 30 N.

From Voltz (Ibid)

τ_o = .0092

From Thekaekara, M.P., R. Kruger, C.H. Duncan, 1969:

Solar Irradiance Measurements from a Research Aircraft, Applied Optics, 8, No. 8 p. 1713-1732, August.

I_o = .0139598 Langleys/minute/5 nanometers.

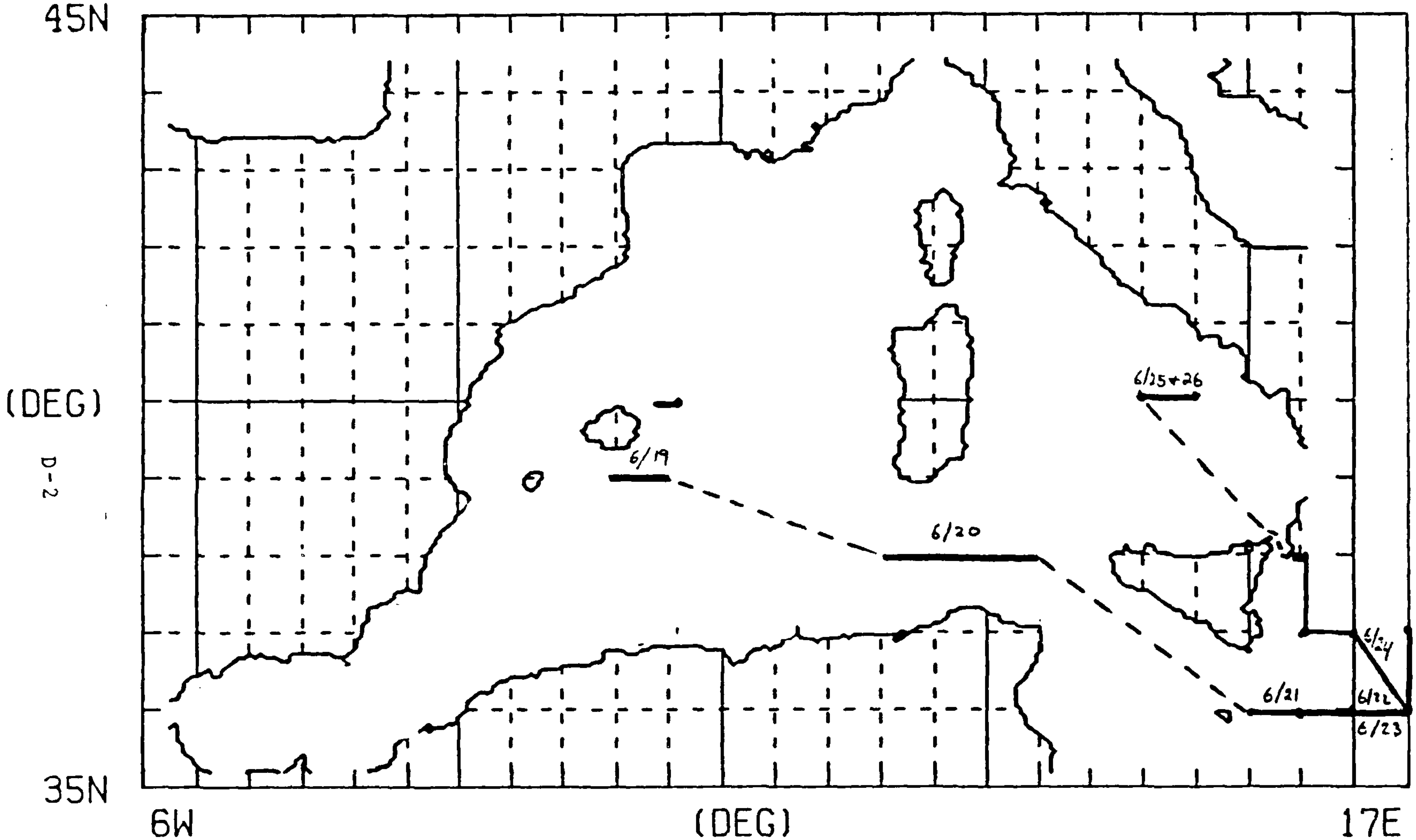
APPENDIX D

OBSERVATIONS AND ELEMENTAL PARTICLE COMPOSITION FROM THE USS AMERICA CRUISE

Data collected by NEPRF personnel aboard the USS America are reported here. Figure D-1 shows the approximate cruise track over which data were collected. Data is reported for daylight hours for the period 19 to 26 June.

Optical depth was calculated from Volz sun photometer readings in the 0.5 micron (green) channel and measured M (solar zenith angle). Particle concentration was measured with a Gardner Small Particle Detector, relative humidity from temperature and dew point data, and sky cover estimation by human observer. Significantly lower visual ranges calculated from the HSS visibility meter, compared to the observers visibility estimate, suggest that flight operations interfered with the HSS measurements throughout the cruise. Visibility reported in the following tables is taken from the manual observations of NEPRF personnnel aboard the America.

USS AMERICA CRUISE TRACK (APPROXIMATE)



USS AMERICA OBSERVATIONS (NEPRF)

Date	Local Time	Optical Depth	Particle #/cc	RH	Visibility	Sky Cover
6/19/86	0900	0.37	-	68%	5 nm	0.2
	1000	0.36	-	82%	5 nm	0.2
	1115	0.44	1350	79%	5 nm	0.3
	1200	0.49	1750	82%	5 nm	0.3
	1300	0.47	1750	84%	5 nm	0.1
	1430	0.47	1900	74%	6 nm	0.1
	1600	0.65	1900	71%	7 nm	0.3
	1700	0.40	1550	77%	6 nm	0.1
	1800	0.42	1550	79%	6 nm	0
6/20/86	0800	0.45	-	92%	4 nm	0.5
	0900	0.45	3600	83%	3 nm	0.6
	1000	0.53	-	93%	3 nm	0.5
	1100	1.04	3600	93%	3 nm	0.8
	1200	0.55	-	93%	3 nm	0.9
	1300	0.43	2700	90%	3 nm	0.7
	1400	0.47	7500	78%	3 nm	0.4
	1500	0.34	3000	89%	4 nm	0.2
	1600	0.37	-	81%	5 nm	0.3
	1700	0.36	-	61%	7 nm	0.5
	1800	0.36	-	61%	7 nm	0.4
6/21/86	1100	0.28	2200	88%	6 nm	0.7
	1200	0.36	1600	76%	7 nm	0.2
	1300	0.43	2400	71%	6 nm	0.2
	1400	0.36	-	81%	6.5 nm	0.1
	1500	0.32	6200	75%	7 nm	0.1
	1600	0.31	4300	69%	7 nm	0
	1700	0.30	-	72%	7 nm	0
	1800	0.23	-	64%	7 nm	0
6/22/86	0900	0.45	-	67%	6.5 nm	0.3
	1000	0.40	5600	69%	6 nm	0.2
	1100	0.35	-	76%	6 nm	0.2
	1200	0.43	2250	82%	6 nm	0.1
	1300	0.43	4000	76%	6 nm	0.3
	1400	0.43	7500	77%	5.5 nm	0.5
	1500	0.66	1750	74%	6 nm	0.3
	1600	0.37	2250	74%	6 nm	0.2
	1700	0.57	1900	71%	6 nm	0.2
	1800	0.68	-	-	7 nm	0.2

USS AMMERICA OBSERVATIONS (NEPRF)
(CONT.)

Date	Local Time	Optical Depth	Particle #/cc	RH	Visibility	Sky Cover
6/23/86	0800	0.30	-	82%	7 nm	0
	0900	0.30	6200	75%	6.5 nm	0
	1000	0.28	3600	74%	7 nm	0
	1100	0.32	4400	78%	5 nm	0
	1200	0.29	4000	78%	6 nm	0
	1300	0.29	1900	71%	6 nm	0
	1400	0.26	6800	74%	5.5 nm	0
	1500	0.32	2700	72%	6 nm	0
	1600	0.28	-	71%	6 nm	0
	1700	0.30	10000	76%	6 nm	0
	1800	0.28	-	77%	5 nm	0
6/24/86	0800	0.29	4400	76%	5.5 nm	0
	0900	0.39	11000	76%	5 nm	0
	1000	0.58	12500	65%	6 nm	0
	1100	0.35	7200	71%	6 nm	0
	1200	0.47	-	62%	6 nm	0
	1300	0.39	8500	62%	7 nm	0
	1400	0.39	3300	66%	7 nm	0
	1500	0.70	4800	77%	7 nm	0.4
	1600	0.68	4000	-	7 nm	0.3
	1700	0.76	-	56%	7 nm	0.7
	1800	0.79	2200	62%	7 nm	0.8
6/25/86	1400	0.26	2200	82%	6 nm	0.1
	1500	0.32	2200	82%	7 nm	0
	1600	0.37	3000	70%	7 nm	0.2
	1700	0.61	9500	78%	6 nm	0.3
	1800	0.33	-	76%	6 nm	0.3
6/26/86	0800	0.47	4800	91%	6 nm	0
	0900	0.45	3000	91%	6 nm	0
	1000	0.83	12000	81%	6 nm	0
	1100	0.40	-	74%	6 nm	0
	1200	0.59	3500	79%	5.5 nm	0
	1300	0.43	2650	74%	5.5 nm	0
	1400	0.50	8500	61%	6 nm	0
	1500	0.61	2400	56%	6 nm	0
	1600	0.40	-	-	6 nm	0

PERCENT OF PARTICLES CONTAINING INDICATED ELEMENT

USS AMERICA CRUISE

Date	Local Time	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	Fe
6/19	1100	0	8	24	42	6	18	0	10	8	4	0
6/19	1330	0	4	48	52	4	16	4	0	8	0	8
6/20	1130	8	28	20	44	0	24	8	24	28	0	12
6/20	1330	24	24	44	60	8	48	0	48	48	0	24
6/21	1130	16	16	24	32	0	24	12	16	28	0	8
6/21	1315		- - - - - No Sample found - - - - - - - - -									
6/22	1240	4	4	48	64	8	36	0	12	24	16	12
6/22	1400	0	12	48	48	4	44	4	28	28	0	20
6/23	1445	16	20	56	64	8	68	0	28	40	0	20
6/24	1530		- - - - - No Sample found - - - - - - - - -									
6/25	1045	32	36	76	80	8	32	12	80	24	0	52
6/25	1200	28	44	84	88	4	68	8	68	20	4	40
6/26	1000	2	16	40	52	4	24	22	22	32	4	20
6/26	1200	14	18	48	52	0	6	4	18	26	0	20
6/26	1500	0	2	30	46	0	46	8	44	16	2	0

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